1. Introduction

This publication, the fourth in the series of Aspects of Dairy Economics, deals with projects undertaken during the 1966/69 research period*.

In previous years there has been a marked emphasis on the role of grassland in milk production, on methods of measuring its contribution to the feeding of livestock and in particular on its potential in replacing relatively expensive concentrates. In addition various studies have highlighted the relative importance of different factors in profitable milk production. The techniques of budgetary control and linear programming have also received attention. Throughout the previous periods there was a pronounced concentration on cost reduction possibilities as well as some emphasis on increasing returns to milk production. The direction of research was largely determined by the problems which faced farmers at that time and by far the most important was the tendency for milk prices to decline.

There can be little doubt that over the years milk producers have acquired considerable confidence in the ability of grass and conserved grass products to replace concentrates and reduce costs of production. They have also been reassured that increased stocking rates were possible, in some cases without marked changes in management, but in all cases provided additional fertilizers were applied and better grazing techniques introduced. Undoubtedly this reassurance has induced dairy farmers to increase their herds. Apart from the investment in the cows themselves, this expansion was possible in some cases with little or no capital investment. In others, new housing and milking systems were erected, involving massive investments of capital. These developments have triggered off a number of studies of structural change in the dairy industry.

The period was also characterized by persistent imbalances of trade and the appearance of a report on *Agriculture's Import Saving Role* by the National Economic Development Council, and the Government's Selective Expansion Programme sparked off interest in agricultural expansion. The influence of these issues is clearly apparent in the research that has been done.

The overall size of the dairy industry in the 'sixties has changed very little. The dairy cow population in England and Wales at June 1969 was 2,746,000 compared with the previous peak level of 2,728,000 at June 1962. Nevertheless, the last decade has been a period of substantial change beneath the surface and, in the research and statistics emanating from the Ministry of Agriculture, Fisheries and Food and the Milk Marketing Board, there has been much emphasis on the measurement of structural change in the industry. Section 2 has accordingly taken the form of a general review of structural change in dairy farming as it has been reflected in the new statistics as well as in the research by the University Departments. It is hoped that this will prove useful to those who want a general guide to the subject as well as the sources available. The section also discusses the results

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* A review of research projects undertaken during 1962–1965 appeared in 'Aspects of Dairy Economics 1962–1965' and was published in 1967.

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of one of the new techniques for handling this kind of data and a more rigorous treatment of the technique itself, which is not available elsewhere, has been given in an Appendix by A. J. Rayner.

The third section examines the implications of structural change for the individual farmer and incorporates particularly studies of changes in technology and their effects on the scale and profitability of dairy farming. It includes summaries of studies of changes in the use of land and feed resources as well as changes in the use of labour and capital.

The fourth section gives an analysis of the implications of obtaining more beef from the dairy herd, a study directly linked to the present Government policy for agriculture. The section also contains a summary of further contributions to the related but perennial problem of seasonal patterns of milk production. The financial repercussions on some Cheshire farmers of the worst epidemic of foot and mouth disease in the history of this Country are investigated. Lastly, milk supply response is investigated with the aid of certain new techniques and the transport of milk is examined.

In the last section of this publication a distinct departure has been made from previous issues since it contains a critique of the techniques used in the research projects summarized elsewhere in the report. This section, written by A. J. Rayner of Manchester University, has been designed to be deliberately but constructively critical from a methodological standpoint and it is hoped that this will be of benefit to future research work. It is designed mainly for students and professional readership.

[NOTE: The numbers in brackets throughout the text after titles of publications and authors names refer to the item listed in the bibliography.]

2. The changing structure of dairy farming in England and Wales

Dairy farming, in common with the rest of the agricultural industry, is experiencing a process of continuing change in its structure, that is, in the number and size of dairy herds, specialization of farms, organization and methods of production and geographical location. The chief factors underlying this process are changes in price relativities of inputs and products and the availability of new technology, providing respectively the stimulus and the tools for better management and new methods by which farmers can achieve growth in their efficiency and profits.

This highly competitive atmosphere has given new prominence and clarity to the factors which confer advantages on some groups of dairy farmers and disadvantages on others in their ability to achieve their hopes or expectations in farming. Such factors as size of farm and enterprise, level of skill and management, ability to invest new capital in the business, the natural endowments of regions and of individual farms are seen to be sources of variation in success in the business of milk production at any level of average prices set by Government or the market. The need for agricultural policies which operate on these structural aspects of farming, side by side with decisions about guaranteed prices and marketing arrangements, is widely accepted and is reflected in Government action—for instance, in the structural measures under the 1967 Agriculture Act and in other schemes such as those for grant-aid to investment.

The same new emphasis is reflected in the statistics and analyses of agriculture produced in recent years. The Ministry of Agriculture, Fisheries and Food has incorporated an economic classification of farms in its regular analyses since 1963 (1) showing the incidence of specialization in various enterprises, dairying among them, and the distribution of businesses by size groups. The frequency distributions published annually since 1961 (2) show the degree of concentration of various enterprises in large units—for instance, of dairy herds and cow numbers in herds of 50 or 100 cows and over. Type-of-farming maps based on the Agricultural Census (3) have shown the location of areas where dairy farming is dominant in varying degrees. The Milk Marketing Board have augmented their established periodic production censuses since 1955 by more detailed analyses, including many structural aspects of dairy farming, based on a Permanent Producer Sample (4). The periodic Milk Costs Enquiries undertaken by University Departments of Agricultural Economics as part of the National Investigation into the Economics of Milk Production also provide useful evidence of developments in the nature of the dairy farm business.

In this section the structural changes revealed by the various statistical sources are reviewed and discussed together with the results of some University studies of the changes and their implications.

CHANGES IN NUMBERS AND SIZE OF DAIRY HERDS

Probably the most significant contemporary trend in dairy farming is the steady decline in the number of producers. The number of milk producers registered with the Milk Marketing Board was 110,690 in March 1963. By 1969 there were 84,720, a decline of over 23 per cent in 6 years. The June Agricultural Censuses for the same years show a similar movement; the number of holdings with one or more dairy cows fell from about 126 thousand to some 91 thousand, or by nearly 28 per cent. When confined to holdings with herds of 6 or more cows, the trend corresponds closely with the Board's statistics, being a reduction from about 103 thousand to 70 thousand, or 23 per cent.

Over the same period the average size of dairy herds has increased. The June Agricultural Censuses show a growth in the average number of cows per herd* from 21·4 in 1963 to 30·1 in 1969, an average annual rate of increase of nearly 1½ cows or 4·8 per cent. The trend towards fewer and larger herds has been achieved in two main ways: first, some of the smaller herds have gone out of production, while secondly, herds remaining have expanded. The size distributions of holdings and cows in the June Agricultural Censuses illustrate these movements.

TABLE 1

Changes in Milk Producing Herds in England and Wales, 1963 *to* 1969

Herd size (cows)	Changes in number of herds		Average cows per herd		Per cent distribution			
					of herds		of cows	
	1963 to 1969		1963	1969	1963	1969	1963	1969
	Number	%						
Under 20	−34,550	− 47·3	9·5	9·7	58·0	42·4	25·8	13·7
20 to 99	− 1,690	− 3·3	35·9	40·3	41·1	55·0	69·0	73·7
100 and over	+ 1,345	+128·1	134·4	144·6	0·9	2·6	5·2	12·6
Total	−34,895	− 27·7	21·4	30·1	100·0	100·0	100·0	100·0

Though some of the reduction in the number of herds of under 20 cows reflects their transfer to higher size groups and another element reflects changes in the statistics of holdings, the size of the reduction points clearly to the preponderance of small producers among those who cease milk production. Equally the rising average herd sizes shown suggest strongly that individual herds are increasing in size throughout the size range. At the end of the period only about 40 per cent of herds were under 20 cows compared with nearly 60 per cent in 1963, and they contained no more than 14 per cent of the total dairy herd, only a slightly larger proportion than was accounted for by the growing number of large herds of 100 or more cows.

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* For the purpose of this section, in references to Agricultural Census data, 'herds' are equated with 'holdings with dairy cows'.

In their publication 'Changes in Milk Output 1963–1967' (5), based on their Permanent Producers Sample, the Milk Marketing Board analysed the number of producers ceasing milk production (outgoers), changes in output among the continuing producers and the numbers of newly registered (and transferred) producers. Annual output of milk rather than number of cows was used as the measure of producer size, so the movements of producers between size groups are affected by trends and fluctuations in yield per cow in addition to changes in herd size. The results are summarized in Table 2.

TABLE 2

Percentage Size Distribution of Various Categories of Producers
1963/64 *to* 1966/67

Category		Size Group (gallons)						Total	
		Very small (under 7,500)	Small (7,500–14,999)	Average (15,000–24,999)	Sub-stantial (25,000–49,999)	Large (50,000–99,999)	Very large (100,000 and over)	per cent	Numbers
All producers	1963/64	22·3	30·4	23·3	18·8	4·5	0·7	100	100,750
Outgoing producers	1966/67	36·8	29·4	18·7	12·2	2·8	0·1	100	17,310
Continuing producers	1963/64	19·3	30·7	24·3	20·1	4·8	0·8	100	83,440
	1966/67	19·3	27·2	22·7	22·7	6·9	1·2	100	
New and transferring producers (a)	1966/67	16·6	24·1	24·8	23·9	8·1	2·5	100	4,440
All producers	1966/67	19·1	27·1	22·8	22·7	7·0	1·3	100	87,880
(Outgoers in 4 years as per cent of 1963/64 producers)		(28)	(17)	(14)	(11)	(11)	(3)	(17)	

(a) Transferring producers are established producers taking over the farms of outgoing producers.

The reduction in producer numbers by 1966/67 is the net result of the departure of about 17 per cent of those who were producing milk in 1963/64 and the much smaller numbers of new producers who entered milk production in the 4-year period. The accompanying increase in the average output per producer stems from (i) the higher departure rate of Small and Very Small producers—two-thirds of outgoers were in these categories in 1963/64, compared with about a half of those who continued; (ii) expansion of output among continuing producers—so that 31 per cent of them were Substantial or Larger by 1966/67 compared with 26 per cent at the outset; and (iii) the above-average size of the new and transferring producers—this category contained proportionately fewer small producers and more large producers than any other category. A special study of new producers (6) distinguished between new producers on farms with no immediately previous milk production and others, the majority, who took over established milk producing farms. The first group, those starting from scratch, were found to be mostly on small farms and had relatively small herds in 1966/67, while the second, probably many of them taking over an existing herd, were well above the average size in 1966/67.

A further analysis in the 'Changes in Milk Output' report examined the trends in output among the 83,440 producers who were in production continuously from 1963/64 to 1966/67. Some two-thirds of these producers showed an upward trend in output during the period, most of them with some fluctuation; one in five, however, increased their output every year, though this behaviour was rather less frequent among small producers.

DAIRY FARMS: SPECIALIZATION AND ASSOCIATED ENTERPRISES

As producer numbers have declined and the remaining herds have expanded the dairy enterprise has become increasingly dominant in the dairy farm business. Milk production has tended to be abandoned more frequently on farms which were less dependent on it than on more specialized dairy farms. Other enterprises associated with milk production have become fewer.

The analysis since 1963 of the Agricultural Census returns in terms of types of farming illustrates these trends. In this analysis each holding is classified according to the proportion of the standard labour requirements* of its stocking and cropping accounted for by the various enterprises in the business. Thus a holding with more than 50 per cent (but less than 75 per cent) of its standard man-days (smds) in dairying is classed as Mainly Dairy while one with 75 per cent or more in dairying is a Specialist Dairy holding; similarly, holdings with more than 50 per cent of smds in other enterprises may be Livestock (rearing and fattening), Pigs and Poultry, Cropping or Horticultural holdings. Some of these main groups are further subdivided, e.g., into Cropping, Mainly Cereals and General Cropping. If no enterprise accounts for more than 50 per cent of smds the holding is classed as Mixed, while holdings with fewer than 275 smds in total are treated as a single group and not classified by enterprise-type. This method of classification is discussed by Napolitan and Brown (24).

The results of the type-of-farming analysis for June 1963 and June 1969 may be compared to show the trends.

The decline of 20 per cent in Dairy holdings (that is, all those with more than half their smds in dairying) is less marked than that in all holdings with dairy cows and is confined to the Mainly Dairy class. Specialist Dairy holdings were in fact more numerous in 1969 than at the beginning of the period. Over a third of all dairy herds were on this highly specialized type of holding by 1969 compared with less than a quarter in 1963, and these holdings carried nearly a half of the total dairy herd. In all, nearly four out of five dairy cows in 1969 were on Dairy holdings—rather more than in 1963.

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* Standard labour requirements are the annual requirements of manual labour needed *on average* for the production of crops and livestock with an addition for essential maintenance and other necessary tasks. The requirements are expressed in terms of 'standard man-days' (smds per acre of crops or per head of livestock) which represent 8 hours manual work for an adult male worker under average conditions.

TABLE 3

Classification of Holdings with Dairy Cows by Farm Type

Type of farming*	Number of holdings with dairy cows		Per cent of total holdings with dairy cows		Average size of herd		Per cent of total dairy herd	
	1963	1969	1963	1969	1963	1969	1963	1969
Specialist Dairy	29,677	30,552	23	34	32	42	35	47
Mainly Dairy	34,903	21,350	28	23	29	39	38	31
All Dairy	64,580	51,902	51	57	31	41	73	78
All other holdings	61,932	39,215	49	43	12	16	27	22
Total	126,512	91,117	100	100	21	30	100	100

* Standard labour requirements per head and per acre were revised between 1963 and 1969 in the light of changes in labour use and technology.

The average dairy herd on Dairy holdings is substantially larger than other dairy herds and grew from 31 cows in 1963 to an average of 41 cows by 1969. The average Dairy holding was itself larger in 1969 with 123 acres of crops and grass compared with 109 in 1963.

Dairy herds became less common on types of holding other than Dairy holdings, though they are still a part of a large majority of Mixed farm businesses. The average herd grew by at least 50 per cent on holdings of all types except Livestock rearing and fattening. The slow growth in dairy herd size on this type of holding was confined to the sub-group in which the rearing and fattening is mainly of sheep. These holdings are mostly in hill areas where conditions are least suitable for dairying. These trends in the occurrence of dairying and in average herd size are illustrated as follows:

Type of Farming	*Percentage of Holdings having Dairy Cows*		*Average Size of Herd*	
	1963	1969	1963	1969
Livestock	28	20	9	11
Pigs and Poultry	20	11	14	22
Cropping	19	11	16	27
Horticulture	6	2	12	19
Mixed	80	72	21	31

The Milk Marketing Board's analysis of outgoing producers (5) classified them according to their dependence on milk measured by the proportion of their standard output* coming from milk. Here too it was found that the highest rates of disappearance occurred among producers who had been the least dependent on milk; nearly 40 per cent of the group with under 20 per cent of total standard output coming from milk, abandoned milk production between 1963/64 and 1966/67 while the disappearance rates for groups more heavily dependent on milk varied from 16·0 to 23·5 per cent.

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* A rough money value given to each enterprise by multiplying acreages and stock numbers by the average yield times the average price.

The type-of-farming analysis of the Agricultural Census shows the other enterprises which occur on dairy holdings. These vary from region to region and depend on the size of farm and the degree of specialization in milk. Table 4 analyses for all dairy holdings in England and Wales in 1965 and 1969 the frequency with which certain enterprises occur, their average size and their importance as part of the totals for England and Wales as a whole.

TABLE 4

Percentage of Dairy Holdings having Certain Enterprises and Average Size of Enterprise—June 1965 *and* 1969

Enterprise	Percentage of holdings having the enterprise		Average size of Enterprise (acres of crops or number of livestock) on holdings with the enterprise		Percentage of England and Wales Crop acreage and livestock number accounted for by dairy holdings	
	1965	1969	1965	1969	1965	1969
Beef cows	11	12	4	5	5	5
Breeding ewes	33	29	60	68	13	12
Breeding pigs	33	24	7	8	19	14
Laying fowls	66	53	140	164	15	11
Wheat	21	13	25	33	14	12
Barley	46	40	26	36	17	14
Potatoes (maincrop and 2nd earlies)	22	16	2	3	7	6

Of the enterprises listed, those most commonly associated with dairying in England and Wales as a whole are laying fowls, barley growing, breeding ewes and breeding pigs. Between 1965 and 1969, however, the proportion of Dairy holdings having these enterprises has declined, though the average size of the enterprises where they have been continued has increased. The individual dairy farmer is thus concentrating more on dairying and a smaller range of secondary enterprises than in the past.

BEEF PRODUCTION FROM DAIRY HERDS

Table 4 has shown that dairy farmers now account for 10 to 15 per cent of the total production of most of the farm enterprises other than milk. Beef breeding is an exception, however, since only 5 per cent of the beef cow herd is on dairy holdings. But this is only one aspect, and a minor one, of the connection between milk and beef production; the fact, for instance, that the majority of calves used for beef are born in dairy herds is of more significance in any analysis of the potential growth of beef production in Britain. Important though they are, the links between milk and beef have not proved easy to analyse in detail largely because of their complexity, since beef production takes place in several stages and a variety of systems and locations, and difficulties can arise in classifying some classes of cattle in the census returns as being for milk or for beef production. Some new information, however, is available from an analysis of the June 1969 Agricultural Census showing the association of dairy cows and beef cows or store and fattening steers on the same holdings.

TABLE 5

Proportion of Dairy Herds with Associated Beef Herds
England and Wales June 1969

Dairy herd size group (cows)	Total holdings with dairy cows	Holdings with dairy and beef cows†		Holdings with dairy cows and steers*†	
		Number	Percent of Column 1	Number	Percent of Column 1
	1.	2.	3.	4.	5.
6 – 19	27,121	5,927	22	14,087	52
20 – 49	37,035	5,637	15	19,084	52
50 – 99	13,123	1,754	13	6,627	50
100 & over	2,395	316	13	1,116	47
Total	79,674	13,634	17	40,914	51
Cows or steers in associated herds:		Number '000	Percent of all cows or steers	Number '000	Percent of all cows or steers
Dairy cows†		405	15	1,372	50
Beef cows		108	17	—	—
Steers		—	—	550	31

* Other male cattle over 6 months excluding bulls.

† The analysis of holdings with dairy and beef cows is considered separately from that of holdings with dairy cows and steers. Holdings with dairy and beef cows may also have steers and those with dairy cows and steers may also have beef cows. Analysis of the overlap between the two groups is not available.

Seventeen per cent or one in six dairy herds (ignoring those under 6 cows) are on holdings with some beef cows also, though the association is rather more frequent among small dairy herds, and a similar proportion of all dairy and beef cows is in these associated herds. The rearing or fattening (or both) of steers beyond the age of six months in association with milk production is a much more frequent occurrence. About half the dairy herds in all size groups have some male stock retained for these purposes, accounting for nearly a third of the steers in England and Wales.

There is, of course, wide variation in size among the associated herds but the average herd sizes on holdings with both beef and dairy cows are as follows:

Dairy herd size group	*Holdings with dairy and beef cows:* Dairy cows	Beef cows	Total
6 – 19	12	7	19
20 – 29	24	7	31
30 – 39	34	7	41
40 – 49	44	8	52
50 – 69	58	9	67
70 – 99	81	14	95
100 – 199	127	19	146
200 and over	323	53	376
Average	30	8	38

In all except the two smallest size groups an average of one in six or eight of the cows in the combined herds is a beef cow, that is to say it is used mainly for rearing calves for beef. In herds under 30 dairy cows, however, the beef cows are on average a quarter or a third of the combined total. The average sizes of the associated herds are somewhat smaller than those of all herds of the two types separately, 34 for dairy herds (excluding herds under 6 cows) and 11 for beef herds, reflecting the higher incidence of this association among small herds noted earlier.

The average dairy herd size and number of steers on holdings where they are associated are as follows:

Dairy herd size group	*Holdings with dairy cows and steers:* Dairy cows	Steers
6 – 19	13	9
20 – 29	24	11
30 – 39	34	13
40 – 49	44	15
50 – 69	58	19
70 – 99	81	25
100 – 199	126	36
200 and over	311	73
Average	34	13

On average those dairy herds with associated store or fattening steers have 34 dairy cows and 13 steers, the latter figure being less than the average of 17 for all steer herds. At the risk of some over-simplification it may be remarked that as herd size increases the number of steers recorded falls progressively below the number likely on average to be born into the dairy herd. In the largest size groups the steers shown are about a half of the approximate number (say 50 per cent of the cow numbers) of male calves probably born, compared with 90 per cent in the 20–29 dairy size group and 75 per cent in the 30–39 group. This might reflect a higher degree of specialization in milk production on holdings with larger herds, especially in relation to the use of grass, causing more male calves to be sold off before or soon after they reach six months of age, than would happen in the smaller less specialized dairy herds.

REGIONAL DISTRIBUTION AND TRENDS IN DAIRYING

Table 6 shows for 1963 and 1969 the distribution of dairy cows and dairy herds and the average size of herd in each Ministry Region of England and Wales.

TABLE 6

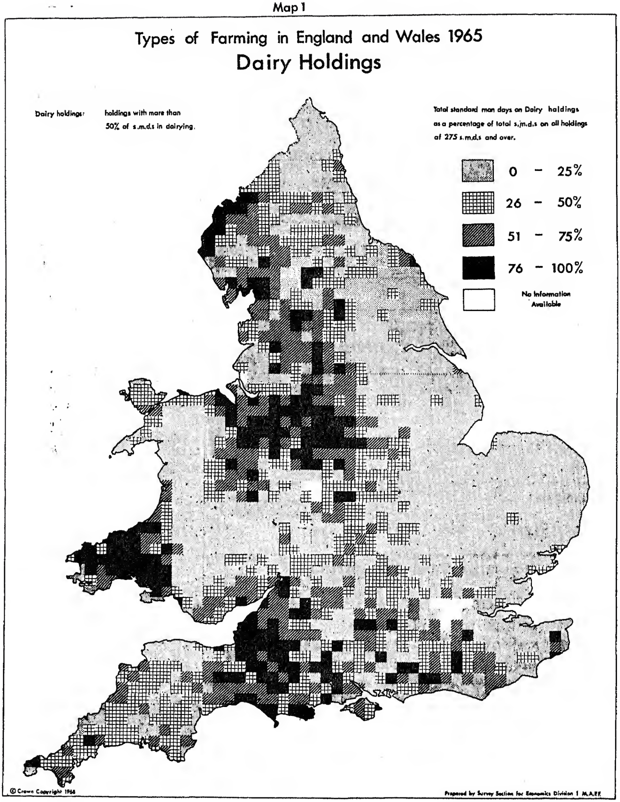
Regional Distribution of Dairy Cows and Dairy Herds and Average Size of Herd in 1963 and 1969

Ministry Region*	Dairy cows		Dairy herds		Average number of cows per herd	
	1963	1969	1963	1969	1963	1969
	%	%	%	%	cows	cows
Eastern	5·7	4·9	5·0	3·9	24·6	38·0
South Eastern	11·6	11·0	8·6	7·8	29·0	42·3
East Midland	7·8	7·4	7·9	7·4	21·0	30·0
West Midland	16·8	16·6	14·6	14·7	24·7	34·0
South Western	25·7	27·4	24·2	25·4	22·6	32·4
Northern	9·1	9·5	9·8	10·2	19·8	27·8
Yorks and Lancs	10·0	10·0	11·2	11·2	19·1	26·8
Wales	13·3	13·2	18·7	19·4	15·2	20·5
England and Wales	100·0	100·0	100·0	100·0	21·4	30·1
Eng. and Wales—Numbers	2,697,236	2,741,713	126,512	91,117	—	—

* Ministry Regions are described in Appendix III

The region with by far the biggest share of the dairy industry is the South Western with 27 per cent of all dairy cows. The South Western and West Midland regions and Wales, the three biggest regions in these terms, together slightly increased their share of the dairy industry between 1963 and 1969 to nearly 60 per cent of the total number of herds and of the total dairy herd. The remainder of the industry is divided broadly in equal parts between the North of England and the East, East Midland and South Eastern regions. The proportionate importance of the latter regions is declining, despite the fact that the East and South East regions show the biggest increases in average herd sizes between 1963 and 1969 and now have by far the largest average size of herd. This reflects the high rates of abandonment of dairying in these parts of England, as shown by the Milk Marketing Board's analysis of outgoers. Though the Board's Regions are not not identical to the Ministry's, that analysis puts outgoers (5) by 1966/67 at about 30 per cent of the 1963/64 numbers in the Eastern and South Eastern regions, compared with under 20 per cent in England and Wales as a whole.

Map 1


Types of Farming in England and Wales 1965
Dairy Holdings
Dairy holdings: holdings with more than 50% of s.m.d.s in dairying.
Total standard man days on Dairy holdings as a percentage of total s.m.d.s on all holdings of 275 s.m.d.s and over.
0 - 25%
26 - 50%
51 - 75%
76 - 100%
No Information Available
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Prepared by Survey Section for Economics Division I M.A.F.F.

The type-of-farming classification of holdings in the Agricultural Census has been followed up by experiments in mapping. The map reproduced here (p. 12) shows the areas where dairy holdings accounted in 1965 for varying proportions of the total farming activity measured in standard man-days. It makes strikingly clear the concentration of dairying as the dominant type of farming stretching from the border areas of Wales through the Cheshire Plain to Derbyshire, in South West Wales, and in the West Country; other rather less well defined dairy areas are in the North West and Southern England.

In addition to the regional analyses of dairying discussed above, there has been published a more detailed study of the structure of the dairy industry at the regional level. The study by V. H. Beynon and E. T.Davies (7) published in 1968 throws considerable light upon the structural aspects of the dairy industry in two counties, Devon and Cornwall. The study was based mainly upon a postal sample survey and its main findings, which relate to 1965 and 1967, are summarized below.

1. In both Devon and Cornwall 75 per cent of farmers with full-time businesses have dairy cows on their farms. Almost the entire dairy cow population in Devon and well over 90 per cent in Cornwall are kept on full-time businesses. The contribution of part-time businesses and residential holdings to dairying in these counties is relatively insignificant.

2. The surveys undertaken by the Milk Marketing Board show that since 1955 there has been a marked reduction in the numbers of farms registered for selling milk in the two counties, whilst cow numbers and herd sizes have been increasing. This is a picture of specialization. Indeed, excluding residential farms, the county surveys indicate that 94 per cent of the dairy cow population in Devon are on farms where milk production contributes over 50 per cent of the total standard output. Specialization in Cornwall is not so pronounced, only 79 per cent of the cows being in the dairying group, whereas 18 per cent are on the mixed type of business.

3. Despite the numerical predominance of the small herds in the Far West, nearly three-quarters of the dairy cows are now in herds of more than 20 cows. Furthermore, it is estimated that over 20 per cent of the dairy cows in Devon and some 15 per cent in Cornwall are in herds of more than 50 cows.

4. The average size of herds in the Far West is difficult to establish because beef cows are used for milk production during parts of the year. Taking only the dairy cows into consideration the average size of herd in both counties is around 21 cows. With beef cows included, quite irrespective of whether they are used for milk, then the average is raised to 23 cows.

5. Beef and dairy production are associated on about a quarter of all farms with dairy cows. The association is stronger in the smaller herds and particularly so on the larger farms with small dairy herds.

6. The predominant breed used for milk production in both counties is now the Friesian, which accounts for over 50 per cent of the total dairy cows. This proportion is still well below the average recorded for England and Wales in 1965.

7. On all farms with dairy cows in the county of Devon the value of milk output averaged nearly 50 per cent of the total ouput; the proportion in Cornwall was 44 per cent. The greatest reliance on milk output occurred in the bigger herds, particularly in those found on farms ranging from 50 to 150 acres in extent.

8. Specialist dairy farms account for about 60 and 50 per cent of total county output of agriculture in Devon and Cornwall respectively. The output from the milking herds in the two counties accounts for 37 and 32 per cent respectively.

9. Labour on the specialist dairying farms accounts for about 58 per cent of the total farm labour force in Devon and 45 per cent in Cornwall.

10. Hay is far and away the dominant method of conserving grass with about three-quarters of the farmers relying entirely on the crop. By comparison silage making is relatively unimportant.

LAND USE AND STOCKING DENSITY IN THE U.K.

The tendency for individual farmers to specialize is reflected in data relating to different Countries and Regions in the United Kingdom. The Economics Division of the Milk Marketing Board (8) has examined the census data relating to the use of land by different agricultural enterprises in various parts of the United Kingdom and the results are set out in a report entitled *The Balance of Arable and Livestock Farming in British Agriculture.*

Over the eleven years to 1966 the barley acreage increased in every area by substantial proportions. The acreage sown to wheat increased significantly only in the South East and South, but over the period there has been a 'westward movement in the boundaries of the chief wheat-growing area of East Anglia. . . . In all areas there was a dramatic downward movement in the acreage of other cereals especially oats'. The increases in the total cereal acreage have been greatest in the South Eastern and Southern regions of England and Wales.

Fodder crop acreages were virtually halved in all areas of England, Wales and Scotland. In the arable areas there have been substantial decreases in grass acreage; in others the acreage has remained static apart from Wales where there has been an increase.

Data on the pattern of livestock distribution mirror changes in the cropping. In the traditional arable areas of the South and South East, total numbers of livestock expressed in livestock units have changed little, whereas in the traditional grazing areas there has been a tendency for numbers to expand. Whereas dairy cows outnumbered beef cows by more than six to one in all areas of England in 1966, the numbers were much closer in the other Countries. There was a marked fall in the relative importance of other cattle over two years, which may reflect a tendency to market cattle at an early age.

With a decreasing grassland acreage and expanding livestock numbers there has been an improvement in the density of stocking in all regions. In England and Wales as a whole the report estimates that the level of stocking improved from 2·20 acres of grassland per livestock unit in 1955 to 1·81 in 1966, which represents an improvement of 18 per cent in eleven years, or 1·76 per cent per annum compound.

The report seeks to show that the improvement in stocking density represents an improvement in the contribution of grassland to the feeding of livestock. A lengthy technical discussion on the technique of measuring grassland productivity is included, which is reviewed in Section 5. The results show that the utilized starch equivalent of grassland increased from 12·9 cwt per acre in 1955 to 15·7 cwt in 1965 — a 22 per cent improvement in ten years, and conclude that the calculated rate of change in stocking density represents a reasonable measure of improvement in grassland productivity.

LABOUR AND PRODUCTION SYSTEMS

The structural changes described in this section have been accompanied by marked trends towards change in organization and methods of production. These are dealt with in detail in the reports on the Milk Costs Enquiry under the title *Costs and Efficiency in Milk Production*, of which the next is in preparation. This will describe the results of the 1968/69 Enquiry and the changes since the 1965/66 Enquiry. The most significant trends concern the growth in the adoption of parlour milking, bulk tanks and cheaper housing, and these have brought about substantial savings in labour and some other costs. The labour force itself is also changing, with a growth of specialization in milking labour and an increasing proportion of the total labour input being supplied by the farmer and his family. Feeding regimes are also much affected by herd expansion since higher stocking densities and avoidance of heavy increases in usage of purchased feedingstuffs are important factors in the profitability of increased output. A study by the University of Newcastle (9) of expanding dairy herds in the North of England throws some light on the causes and effects of increasing herd size. The results are described in the next section. They show that farmers look to expansion to provide the economies of scale by producing more output with a less-than-proportionate increase in costs and that economies of labour, higher stocking densities and better use of grassland are in fact achieved on many farms with expanded dairy enterprises.

FUTURE TRENDS

It is likely that recent trends will continue and that an increasing proportion of milk will be produced by fewer but larger herds. In a paper published by the University of Manchester, 1969, Colman and Leech (10) attempted to predict the structure and output of the dairy industry of England and

Wales in 1970/71 and 1975/76 at both the national and regional levels. The base period for this analysis was 1963/67 and the data used were obtained from the Milk Marketing Board's Permanent Producer Sample. A summary of the forecasts is set out in Table 7. The regions are those used by the Milk Marketing Board*. The method of forecasting used is described in Section 5 and Appendix 1.

TABLE 7

Summary of Predictions made by Colman and Leech

Milk Marketing Board region	Percentage decline in producer numbers from 1966/67		Percentage distribution of producers		Percentage change in output from 1966/67		Percentage distribution of milk output	
	1970/71	1975/76	1970/71	1975/76	1970/71	1975/76	1970/71	1975/76
Northern	23·0	41·5	10·6	9·8	− 6·1	−12·6	8·8	7·9
North Western	13·7	25·7	22·3	23·3	+ 2·9	+ 4·9	21·7	21·4
Eastern	24·2	42·5	3·6	3·3	− 2·2	− 7·3	4·1	3·8
East Midland	22·6	40·8	4·6	4·3	+ 1·5	− 5·7	5·2	4·7
West Midland	17·9	31·1	8·5	8·7	+ 8·0	+13·3	10·2	10·4
North Wales	18·6	33·4	7·1	7·0	+ 8·4	+17·0	4·5	4·7
South Wales	15·8	29·4	11·7	11·9	+ 6·3	+17·7	7·4	7·9
Southern	25·2	42·2	3·8	3·6	+13·5	+20·1	6·3	6·5
Mid-Western	18·5	32·1	9·7	9·9	+12·8	+21·1	15·2	15·8
Far Western	16·5	29·8	13·9	14·1	+ 4·3	+ 8·6	9·5	9·7
South Eastern	23·7	38·9	4·2	4·1	+ 7·3	+11·7	7·1	7·2
England and Wales	18·3	32·7	100·0	100·0	+ 5·2	+8·4	100·0	100·0
England and Wales —absolute numbers	17,022	30,473	76,058	62,607	106·2 million gallons	170·9 million gallons	2,146·6 million gallons	2,211·3 million gallons

Colman and Leech forecast that the decline in the number of producers and the increase in herd size would continue at least up to 1975/76, both regionally and nationally, and that there would be an increase in milk output of about 8 per cent between 1966/67 and 1975/76. They also predicted that there would be a slight shift in the regional distribution of producers and output. The relative number of producers and output might be expected to fall in the Northern, Eastern and East Midland Regions. By 1975/76, the North Western Region, the largest, might be expected to account for a higher proportion of producers but a slightly smaller proportion of national output.

These predictions are broadly consistent with the conclusions drawn from the University of Exeter survey of Devon and Cornwall, in which Beynon and Davies concluded that:

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* These are described in Appendix III

> 'The broad picture which emerges . . . suggests the trend towards larger herds and more and more Friesian cows are well under way in the area. It is also clear that the possibilities for further concentration in the hands of fewer producers and the greater use of the more productive dairy breeds have not yet been fully exploited. There is also considerable evidence that many small dairy farmers are diffusing their energies far too widely and thereby losing the advantage of specialisation. In particular beef cows are still being kept for producing milk as well as beef for sale. In the process farmers are sacrificing opportunities of increasing output and profit.
>
> The analysis suggests that there is scope for improvement in the use of resources but it is doubtful whether any special measures are necessary to achieve this improvement. Indeed the age distribution of the dairy farmers in the region suggests that there is a high proportion of small herds operated by older farmers. It is doubtful whether these will eontinue in existence after the effective farming life of their present operators.'

The implications and requirements of further expansion and greater concentration of the national dairy herd are likely to resemble those identified by Winter, Evans and Johnson in their report on herd expansion in the North of England referred to earlier (9). Further expansion of herd size will probably be associated with more efficient use of labour and probably a more intensive and efficient utilization of grass to contain expenditure on feedingstuffs. The main requirements of these economies are a continued progress in farm management techniques and the ability of producers to use them together with continued adoption of the latest technologies. To attain these ends, it is probable that investment will be required in buildings, fencing, farm roads and machinery. The feeding operation may also be significantly affected both by the handling problems associated with larger quantities of feed required by bigger herds and through the greater labour requirement involved. The pressure to reduce costs may focus attention on more careful rationing of concentrates. The practical consequences of these requirements would be an increase in the use of such items as automatic concentrate feeding equipment, self-feed silage and specialized milking and housing units.

3. The Effect of Changing Structure on the Individual Dairy Farm

THE review in the previous section has shown that much emphasis has been placed in recent years on the measurement of structural change in the dairy industry. At the same time individual farm studies have tended to concentrate either on the effects of the technological innovations that have been part of this process, or on the economic forces that have put pressure on producers to improve their income by improved efficiency. In a decade of only modestly increasing prices to producers and sharply increasing costs much emphasis is given in the studies considered in this section to ways and means of improving the productivity of resources employed by the industry, particularly land and labour which have been subject to the steepest increases in cost.

LABOUR AND CAPITAL PRODUCTIVITY

Several studies have dealt in various ways with the productivity of labour and capital. The study by Winter and others at Newcastle (9) considers in detail the effects of increasing herd size on the dairy enterprise in relation to other enterprises on the farm and a detailed budget of the labour economies and capital requirements. The study by Williams and Jones (11) considers labour productivity with different systems of milking and housing cows and different herd sizes but omits any attempt to treat the capital problem. Wynne (12) has tried to measure the factors associated with improved labour productivity over time.

In the Northern region the authors of the Newcastle study considered a sample of farmers with over 40 cows who had expanded their herds substantially in the period 1960 to 1966. Various aspects of the expansion process were examined: the farmers' reasons for expanding the scale of dairying operations; the method of obtaining extra cows and providing the additional feed; the capital investment in expansion; labour utilization; sources of capital and the profitability of the investment.

After initial selection by postal questionnaire to 1,000 producers, the detailed records of 74 farms were analysed. Herd size on the 74 farms increased from 45 to 80 cows.

The views expressed by producers in this study left no doubt as to their conviction that increased herd size was an answer to the economic problems posed by rising costs. 'They believed' according to the authors 'that increasing the size of the herd would provide a key to greater profit by providing greater output with less than commensurate increase in costs. Such cost saving, they thought, would be principally achieved through labour economies and by spreading overheads.'

The report attempts a detailed analysis of how far these economies were in fact achieved in practice. Almost all the farms were manned with hired labour and the average number of workers was reduced slightly from 3·2 per farm in 1960 to 3·1 in 1966. With the increase in herd size in the period, however, the average number of hours per cow of direct dairy labour (e.g., milking, feeding, cleaning sheds, etc.) was reduced from 90 to 42 hours per cow per year. In 1960 five of the 74 herds were handled by one man; by 1966, thirty-two of the herds were operated by one man. On several of these farms, however, the regular herdsman was relieved for one or two days each week so that the total work for the week required more than one man's labour.

Substantial capital investment was undertaken to achieve these economies. At the beginning of the period all the sample farms were using cow sheds in which the cows were milked as well as housed. At the end of the period all the farms had changed to parlour milking and the cows were housed in covered yards, many of which were equipped with cubicles. Pipelines had been installed on 60 of the farms and 33 of these ran direct to bulk tanks.

'The extent and cost of improvements to the dairy enterprise varied widely as between farms. In the case of 15 farms completely new layouts were built (Category A). On 30 farms the improvements consisted of modifications to existing buildings (Category C). On the remaining 29 farms some combination of new buildings and modifications to old ones was adopted (Category B).

'All but two of the investment schemes were grant-aided and, taking the farms as a whole, the grants represented 25 per cent of the total cost.'

TABLE 8

Cost of Improvements

	Number of farms	Average total cost per farm	Cost per cow		Range in cost per cow			
		£	£	s.	£	s.	£	s.
1. *Gross costs*								
A.	15	13,060	148	12	61	6	292	0
B.	29	8,235	105	10	46	10	256	12
C.	30	4,776	61	4	21	18	136	2
2. *Net costs*								
A.	15	9,320	106	0	44	16	212	10
B.	29	6,265	80	6	36	10	200	6
C.	30	3,708	47	10	21	18	104	14
All farms	74	5,850	73	2	21	18	212	10

The authors prepared a budget for the average position of the 74 farms before and after the changes made at constant 1966 prices, which is reproduced below.

Table 9

Budget of Before and After Change Positions

Before 45 cows average yield 800 gallons		*After* 80 cows average yield 800 gallons	
	£		£
Total gallons 36,000 @ 3s. 3d.	5,850	Total gallons 64,000 @ 3s. 3d.	10,400
Value of calves @ £9 per cow .	405	Value of calves . . .	720
Total	6,255	Total	11,120
Feeds			
Concentrates @ £26 per cow .	1,170	Concentrates	2,080
Bulk foods @ £18 per cow .	810	Bulk foods	1,440
Grazing @ £10 per cow . .	450	Grazing	800
Labour			
90 hrs per cow = 4,050 hrs @ 6s. 3d.	1,266	42 hrs per cow = 3,360 hrs @ 6s. 3d.	1,050
Miscellaneous expenses £20 per cow	900	Miscellaneous expenses .	1,600
Herd depreciation @ £3 10 per cow	157	Herd depreciation . .	280
Total Costs	4,753	Total Costs	7,250
Net margin . . .	1,502	Net margin . . .	3,870
,, ,, per cow . . .	33	,, ,, per cow . .	48
		Extra Costs	
		New investment	
		(Annual charge of 12% on original net cost of £73 per cow)	730
		Extra fertilizer	
		80×1·46 acres×£3 19 0 .	461
		Total costs . .	8,441
		Net margin .	2,679
		Net margin per cow	33

The construction of this budget might well be criticised in a number of respects especially in its treatment of feed costs and miscellaneous expenses. The authors stress its tentative nature. However, when the capital cost of the additional investment of £73 per cow is taken into account it tends to suggest that no overall economies of scale were achieved. Margin per cow was £33 before and £33 after the change when herd size had been nearly doubled. The additional income in other words was solely a matter of more cows. This brings out the importance of capital grants since, if the capital cost per cow had been £98 instead of £73, there would clearly have been a marked reduction in the margin per cow.

In practice of course the money saving on labour was a great deal more than the budget shows, since wage rates rose from about 4s. 4d. per hour to 6s. 3d. per hour over the period, which means that, had hours not been reduced, labour cost would have risen from £877 to £1,266 for a herd of 45 cows. In practice the labour bill at the end of the period was £1,050. This saving was only possible because of herd expansion which required extra land despite some increase in stocking rate. When allowance for alternative uses of this land is made at a gross margin of £20 per acre, it can be shown that, on average, labour productivity was below the 1960 level when wage levels were low but substantially better than would have been the case without expansion. The rate of return on the extra capital investment at capacity remained between 11 and 12 per cent between 1960 and 1966 despite the substantial increase in wage rates. It would have been less during the period when herd size was being built up to 80 cows and higher as numbers continue to rise, but its low level emphasizes the need to expand to capacity as quickly as possible.

It is a great pity that the study by the Newcastle department is the only one to give detailed farm information of the actual level of investment necessary to achieve improved labour productivity on a group of dairy farms. The lack of detailed information on capital is a serious drawback in current discussion of farm problems. Two other studies, those by Williams and Jones (11) and by Wynne (12) have nevertheless concentrated attention on the effects of herd size and the systems of handling cows on labour productivity.

The study by Williams and Jones attempts to analyse the effects of differences in herd size and differences in systems of operation on labour productivity on herds in the Costings sample of 1965/66*. Herds were classified into groups according to place of housing, place of milking and method of milking. On its own, place of housing was found to make little difference to labour productivity. On the other hand, both place of milking and method of milking in different combinations influenced labour productivity.

The switch from cowshed to parlour milking with simple 'bucket and in-churn' milking used in both cases made a very substantial improvement to labour productivity. The addition of a pipeline in a cowshed made a substantial difference to productivity but rather less in a parlour unless it was accompanied by the addition of a bulk tank as well. The addition of a bulk tank to a parlour milking system added substantially to the labour productivity. The average improvement as a result of adding a bulk tank to a parlour system was estimated at about ten hours per cow per year. In practice, no doubt many producers plan to use the labour freed by the use of a bulk tank by adding to the size of their herds and an example using the equations of the paper may serve to illustrate the point.

The labour requirement for an additional cow in a parlour/pipeline/bulk tank system was 41 hours compared with a labour requirement for an additional cow in a parlour/pipeline to churn system of 51 hours. In a herd of, say, 50 cows handled in a parlour/pipeline to churn system one might assume that the addition of a bulk tank would save 500 hours labour in a year. If the labour freed is effectively utilized, there is therefore a significant reduction in costs. Probably the easiest way to utilize the freed labour on most farms would be to expand the dairy herd, and one might say, therefore that the addition of a bulk tank in this example would enable a further 12 cows to be added to the herd without adding to the labour necessary to handle it.

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* The National Investigation into the Economics of Milk Production—1965/66 Milk Costs Enquiry.

Other examples can be worked out from the equations of this paper, but the two most important technical improvements made in handling cows would appear to be the change from cowsheds to parlours as the place of milking and the addition of a bulk tank to the system. The authors conclude, however, by attempting to set changes in systems of handling cows in perspective. They suggest that, if the cross-section analysis is used to explain the changes over time, the change in technology would explain about one-quarter of the improvement in labour productivity, whilst the other three-quarters was explained by the change in herd size itself. It is admitted, however, that the cross-section analysis is only capable of explaining two-thirds of the total improvement over time. The authors suggest that when future random samples are available there will be scope for extending the analysis of labour productivity using both a cross-section analysis and the change over time.

Wynne's analysis (12) seeks to isolate the effects of changes in herd size from the general trend towards improvement in labour productivity over time on previous 'volunteer' Milk Costs samples. An analysis is made of herds with more than 20 cows in the period 1948/49 to 1961/62. Wynne concludes that the reduction in hours due to factors other than herd size averaged 4·1 per cow per year in the period 1948/49 to 1961/62. Using his equation to predict the results by herd size groups in 1965/66, the conclusion is reached that the 'volunteer' samples used until 1965/66 overstated the true level of labour productivity by 4 to 5 per cent in each herd size group.

FEEDING PRACTICES AND PRODUCTIVITY

Somewhat slower progress has been achieved in recent years in improving the productivity of feed resources than in improving the productivity of labour in the milking of cows. Bulk feeding of livestock in the non-grazing season is an arduous task, making heavy demands on manual labour. Control of the quality of fodder makes considerable demands on the skill of management and is dependent, to a large extent, on the weather. Self-feeding of silage might appear, therefore, to be a big step towards the solution of these problems, and the appearance of growing numbers of tower silos on the landscape of this country prompted Beynon and Godsall (13) to carry out an investigation on their likely impact.

A tower silo eases the problem of quality control by controlling the circulation of air through grass and undried grain. Tower silos are designed to provide relatively air-tight conditions. In the presence of oxygen, grass respires and produces carbon dioxide. If the supply of oxygen is cut off, respiration ceases and the appropriate bacteria produce lactic acid to give a well-preserved silage. The tower silo is supposed to conserve grass at a high dry matter content and reduce the tonnage carted and conserved compared with traditional techniques. Similar claims are made for improved quality in grain storage. Part of the object of the authors' study was to test how far these claims are justified under commercial conditions.

The sample of farms examined was small. There were 21 farms examined, 12 of which had silage towers and 9 had grain storage towers. Farmers were asked first of all the reason for adopting a tower silo. The dominant reason given for adopting silage towers was to save labour, although this reason was closely followed by the desire to eliminate wastage. The desire to eliminate wastage compared with traditional methods predominated amongst those with a grain tower.

The study shows that, in budgeting the capital cost, it is extremely important to include not only the cost of the tower itself but also the allied capital equipment, since the cost of the tower accounts for less than half of the total capital cost net of grants. The other essential equipment consists of loading and unloading equipment, dump box and blower (loading) and open type auger and manger (unloading) and harvesting equipment—a flail mower, chop harvester and tipping trailers. The net capital cost for these items, as estimated by Beynon in a subsequent article (14), at January 1967 prices is set out in table 10.

TABLE 10

Net Capital Costs of Silage Tower and Allied Equipment
(capacity approx. 17,000 cubic feet and based on January 1967 prices)

Equipment	Type of Tower				
	Galvanized	Concrete store	Vitreous enamel		Glass fibre
			Top unloading	Bottom unloading	Top loading
	£	£	£	£	£
Tower silo	2,100	1,729	2,373	2,671	2,730
Allied equipment: loading and unloading	1,950	1,950	1,950	1,965	2,240
Harvesting	2,050	2,050	2,050	2,050	2,050
Total	6,100	5,729	6,373	6,686	7,020

The object of the tower silos is to save labour and improve the feed economy of the farm. With regard to labour, the authors conclude as follows:

> 'The use of tower silos and mechanized feeding systems rarely result in fewer men being employed, although it is not impossible on the larger farms. However, labour economies do occur on most farms, but any labour saved is usually taken up in expanding the size of business. On the present sample, it was found that as much valuable time was devoted by the farmer himself as by a paid manager to the supervision of all operations, and to the maintenance of all equipment in working order. The position, therefore, is one of replacing the

> cheaper general farm worker by a more expensive supervisor. This may be a temporary phase during which farmers acquire more knowledge, farm staff are trained and manufacturers improve their designs, and it is hoped that the system eventually becomes reliably automatic'.

The main saving from a tower silo is to be found in a reduction in the wastage involved in conservation. Whilst farmers have begun to use grass more skilfully in recent years, 'similar progress has not been achieved in conserving grass. The spate of new systems and the adaptation of old ones bears testimony to the fact that successful conservation has so far eluded most farmers'.

The impact of a tower silo on the use of grassland arises because, through the reduction of wastage, it results in a reduction of the land necessary to obtain a given amount of silage. A greater quantity of conserved product, in other words, is obtained from the same acreage. Grazing requirement will, of course, remain the same, but the stocking rate can be increased through the reduction in acreage required for conservation. The improvement in the level of stocking that can be expected is unlikely, according to the authors, to be more than 5 to 10 per cent. The other aspect where improvement is claimed is in the quality of silage. The authors point out that good quality silage can be made with other techniques and they have no evidence to suggest that there is a definite improvement due entirely to the tower storage technique. The situation is examined at two levels of yield (850 and 1,000 gall) and different calving patterns where the improved silage replaced concentrates previously fed for all winter milk at 4 lb per gallon (i) for the first ½ gallon during winter (B), (ii) for first 1½ gallons during winter (C), (iii) for the first 1½ gallons and 7 lb barley fed for the next 2 gallons during winter (D).

A summary of the results as subsequently published by Beynon (14) is set out in table 11. The calculations in this table relate to the combined effect of increased stocking at the rate of 5 per cent plus the substitution of silage for concentrates at the three rates sugested above. Increasing stocking alone would not justify the investment, and neither would an increased production from forage of only ½ gallon per day in winter. To provide a reasonable level of return on the additional capital, additional production from silage to replace concentrates must be at a rate of 1½ gallons per day.

The authors conclude from this analysis that farmers should plan very carefully the changes in their business before investing in a tower silo. Claims made for towers in reducing wastage have been over-generous. With two tower silos, on the other hand, it is easier to obtain a reasonable return on the capital than with one. Capacity is doubled but the capital outlay is not, since the loading and unloading, and harvesting equipment can be utilized for the two towers.

TABLE II

Summary of Percentage Total Returns on Capital and Percentage Returns Available to Farmers on Investments in Tower Silos for Grass

Average Annual Yield	*Returns on capital*	Situations											
		Vitreous enamel bottom unloading			*Vitreous enamel top unloading*			*Concrete stave*			*Galvanized*		
		B	C	D	B	C	D	B	C	D	B	C	D
		per cent											
I 850 gallons with cows calving all the year round	Total	18·1	36·7	46·6	18·9	38·2	48·6	20·7	42·0	53·4	14·6	39·7	50·6
	Available to farmer	Nil	8·0	14·7	Nil	9·1	16·2	Nil	11·9	19·6	Nil	10·2	17·6
II 850 gallons with cows calving Oct./Nov.	Total	18·8	40·8	58·5	19·6	42·6	61·1	21·5	46·7	67·1	20·4	44·3	63·5
	Available to farmer	Nil	10·8	22·8	Nil	12·1	24·7	Nil	15·1	28·9	Nil	13·3	26·3
III 1000 gallons with cows calving all the year round	Total	19·9	39·0	50·8	20·8	40·7	53·1	22·9	44·7	58·2	21·6	42·4	55·2
	Available to farmer	Nil	9·6	17·6	Nil	10·8	14·2	Nil	13·7	22·9	Nil	12·0	20·7
IV 1000 gallons with cows calving Oct./Nov.	Total	20·5	42·5	62·1	21·4	44·4	64·8	23·5	48·7	71·2	22·2	46·1	67·4
	Available to farmer	Nil	12·0	25·3	Nil	13·3	27·2	Nil	16·4	31·7	Nil	14·5	29·0

THE ASSESSMENT OF EFFICIENCY IN THE USE OF TOTAL FEED RESOURCES

The article by Williams and Jones (11) attempts an overall assessment of the industry's use of feed resources in 1965/66. The feed situation is examined through the analysis of five basic factors: yield per cow, stocking density, output per forage acre, utilized starch equivalent per forage acre and margin over feed cost per forage acre. The analysis concentrates on explaining the reasons for inter-farm differences in those factors. The claim is made that detailed statistical treatment improves the description that can be made of the overall use of resources by the industry. Whilst the analysis gives pointers for farm management, warning is given that the relationships should not be applied directly to an individual farm.

The main results of these authors are summarized in the following paragraphs.

(i) *Yield per Cow.* The analysis of yield per cow left a high proportion of the differences in yield between farms unexplained. Nevertheless, there were certain firm conclusions from this important relationship.

  (a) The largest influence on yield difference between farms was the level of concentrate feeding, but concentrates appear to be used beyond the economic level of many farms. It is suggested that at the average level of concentrate feeding (23 cwt per cow) an additional cwt yields only 5¾ gallons. The authors stress that this relationship is unlikely to hold on the individual farm, but they suggest that it supports the point that on many farms concentrates are being wastefully used when high levels of concentrate are fed to cows of low potential.

  (b) The calving interval also had an important effect on annual yield. A reduction of calving interval by 10 days on average increases yield by approximately 10 gallons. A reduction of the calving interval can, therefore, make a substantial difference to the margin per cow achieved.

  (c) There was no relationship between milk yield and stocking rate with other things held equal. In other words, as stocking rate is increased there is no perceptible reduction in yield on the majority of farms.

  (d) Just over 40 per cent of the variation between herds remained unexplained, which is only about 10 per cent more than the variation explained by concentrates. With the data of the sample, it is not possible to say how far this is due to chance, to differences in the yield potential of the cows, to differences in managerial ability, or to other factors. However, the most difficult variable to include in the analysis is the yield potential of the cow, and a satisfactory solution to this still has to be found.

  (e) Breed was found to be an important source of differences in yield between herds. When the effect of differences in feeding levels and calving interval etc., were removed, Friesian cows had an advantage over Ayrshires of 70–80 gallons per cow per year.

(ii) *Stocking Rate and Grass Utilization.* The analyses of stocking rate, milk output per acre and utilized starch equivalent per acre, focus attention on the productivity of grassland. They leave little doubt of the importance of high stocking rate to improve the economic utilization of feedingstuffs on the farm. Utilized starch equivalent per forage acre increases sharply with stocking rate, and the analysis strongly suggests that on many farms grassland is under-utilized. The major management problem seems to be to improve the *utilization* of grass rather than increasing its *production.* It is shown that heavy feeding of concentrates reduces the effective use of grass by reducing the consumption of herbage.

It has often been said that many farmers tend to under-utilize their grassland resources in order to allow a safety margin of feed against the possibility of bad weather. This reasoning is believed to be fallacious since the analysis shows that there is no tendency for the rate of improvement in the utilized starch equivalent of grass to diminish as stocking rate increases. It is argued that a higher stocking rate steps up the whole agricultural cycle and hence improvement in the rate of stocking to a certain extent enables further improvements to be made.

(iii) *The Margin over Feed Cost.* The analysis of margin over feed cost per acre points again to a high stocking rate as the easiest means of improving the profitability of an expanded herd. The fact that some farms are using concentrates at uneconomic levels is clearly brought out by the fact that margin over feed cost *declines* as concentrate feeding is increased. Bulk feed usage was measured in terms of dry matter and the analysis showed that there was no tendency for margin over feed cost to improve as fodder usage per cow was increased; in fact there was a decline in margin over feed cost as the bulk ration was increased. The analysis of yield showed that there was little improvement as bulk feed increased. The authors point out, however, that the analysis of fodder is fairly crude because of the limitations of the data which do not make adequate allowance for the enormous variation in quality that almost certainly exists between farms.

A NOTTINGHAM FARM STUDY

A paper by Bessell (15) seeks to use a series of regression models to establish levels of economic performance in the use of feed resources on a group of farms in Leicestershire and Northamptonshire. The study was made on data collected under the Dairy Management Scheme of the National Agricultural Advisory Service in the East Midland Region. There were 34 farms in Leicestershire and 51 farms in Northamptonshire.

The main analysis starts with a calculation of the distribution of farms according to the proportion of their total starch equivalent requirement obtained from forage (including grazing). On 46 of the farms 66–75 per cent of their starch equivalent requirements for their cows was obtained from forage crops, and the main analysis takes place on this group of farms.

The analysis seeks to explain the relationships between the level of the major inputs of forage acres, concentrates (cwt per cow) and nitrogen (units per forage acre), and the level of yield. Just over half the variation in concentrate input is explained by the other variables, 10½ per cent of the forage acre input, but only 6 per cent of the variation in nitrogen input. These levels of explanation are regarded as unsatisfactory for the provision of input/output relationships and so the analysis is confined still further to the 'relatively efficient' forage users. 'These farms were picked by means of a relationship between nitrogen units per forage acre and Utilized Starch Equivalent per forage acre, the 'relatively efficient' being defined as those who obtained a higher yield of starch equivalent than the relation predicted'. This confined the analysis to a sub-group of 23 farms whose method of selection ensured 'representation over the complete range of nitrogen use, the variable with the largest variance with margin and stocking density'. In the analysis of this sub-group 71½ per cent of the concentrate input was explained in relation to yield and the other inputs, 53 per cent of the land input in terms of forage acres and 31 per cent of the nitrogen input. The author comments that the relatively low explanation of the nitrogen input 'reflects the greater risk and uncertainty attached to the use of fertilizers for obtaining feed and successfully utilizing it compared with the feeding of concentrates'.

The relationship between inputs of nitrogen, concentrates and forage acres per cow is a complicated one statistically since these inputs are simultaneously determined and a single equation model is inadequate to determine the optimum level of each input. A perfect model is not possible with this kind of data but, as a compromise, Bessell adopts a model in the form of a 'causal chain' by means of which each input is separately calculated in an individual equation. The individual farm results are then examined in detail in relation to the model, to judge the efficiency of resource use. In the first place, the model is applied to the farms in the 'relatively efficient' sub-group itself (Group A); then to the remaining farms with 66—75 per cent of U.S.E. from forage (Group B); then to farms obtaining less than 66 per cent of U.S.E. from forage (high concentrate users) (Group C) and finally to farms obtaining more than 75 per cent of U.S.E. from forage (intensive grassland farms) (Group D). In this treatment, the author points out, farmers in each group are being judged according to 'the average environmental conditions and the average operating efficiency of farmers in Group A'.

As a result of detailed scrutiny of these groups, the author concludes as follows:

> 'The most important general conclusion . . . is that it did not pay to farm forage in an extreme manner, no matter whether the extreme manner was to rely on grass as little as possible and heavily on concentrates or to rely largely on grass with a low concentrate use. It is much more likely that the majority of farmers with extreme feeding policies would find it easier to achieve a good margin by following a middle course between the feeding of concentrates and fodder crops. This does not mean that good margins cannot be obtained from extreme feeding policies – only that these policies carry a greater degree of risk and uncertainty—. . . . '

IMPROVEMENT OF FEED RESOURCE USE OVER TIME

Wynne's study (12) attempts to assess the amount of improvement in the efficiency of feed resource use in farms costed in the National Investigation since before the war.

> 'Before the war the average yield per cow in the main group of costed herds was near to 650 gallons and on average each cow consumed almost 23 cwt of concentrates, of which less than 1 cwt was home grown corn. By the early 1960s yields were about 830 gallons and concentrate feeding was still only about 22 cwt per cow, of which 4 cwt were home grown corn and the rest purchased'.

The improvement in the efficiency of concentrate usage has nevertheless been slow. Wynne's analysis shows that concentrate fed per gallon has been reduced by ½ lb over a ten year period. There have been many factors in the improvement in feed relationships over time. Dairy cake has improved in quality over the years. Supplements are more adequate and there is more concentrated cake in use. The big switch from other breeds to Friesians accounts for roughly half of the improvement and much better use is now made of grazing and fodder. Health is also much better and there is no evidence of increased veterinary costs in real terms.

Another source of improved efficiency has been the reduction in the real cost of herd replacement—partly due to improved health of the cows, giving a longer herd life, and partly due to better prices for cow beef. Wynne also notes the improvement in calf returns, but points out that 'what has always been surprising is how few dairy farmers get the best calf prices'

Finally, the author attempts to measure the improvement in land usage over time. There are many problems of estimation but before the war it is estimated that the land requirement was nearly 3 acres per cow for all foods grown on the farm. 'Cost figures indicate that little in the way of fertilizers was applied to grazing, and individual farm records confirm that at that time, with very cheap purchased feed available, pasture was little more than exercise ground for cows on many farms'.

In the early sixties, the land use had fallen to below 2 acres per cow and has undoubtedly fallen well below that since. In terms of starch equivalent, Wynne estimates that pasture grass provided 11½ cwt in the period 1936–38 compared with 13½ cwt in 1960–62. 'It will be noticed that the main direction which the utilization of grassland has taken is in heavier stocking. The cows are apparently only getting slightly more food value from pasture than before the war, but they are obtaining it from a smaller acreage'.

OPTIMUM FEEDING POLICIES

Linear programming has in past research been used to identify a profit-maximizing feeding policy for dairy cows. One of the factors not considered hitherto in the use of this approach is the variability in forage crop yields from year to year which may create difficulty in identifying a genuinely optimum solution. Gunn and Silvey (16) at Cambridge have attempted to tackle this problem.

The authors begin by pointing out that if a profit-maximizing policy is identified, using forage yields averaged over time, the profit indicated by the model may be higher than the profit which can actually be achieved. In a year when average forage yields happen to arise, then the profits indicated by the model could in fact be achieved but, in years of below-average yields, the extra costs incurred would be greater than the benefits which arise in years of forage surplus.

When forage yields are below average, either output of milk will fall or the feed deficit will be made up by other forms of feed, usually concentrates. When forage yields are high, it is likely that the extra forage will be used less productively or even wasted. Since, therefore, the gains from high yields are less than the losses from low yields, the authors argue that on average the maximum profit indicated by a linear programme based on average yields is unlikely to be attained in practice.

To illustrate the effects of this on a linear programme solution, the authors set up a model first of all, based on average forage yields, and then proceeded to show the effect of allowing variation in forage yield. The model specifies a maximum lactation yield of 1,000 gallons for Friesian cows and a linear response to concentrate feed. Revenue-generating activities were milk production, calf sales and cow sales. Monthly milk prices were used and calf, cull cow and heifer replacement prices varied with month of calving. Feed producing activities were short and long term leys, kale, barley, balanced concentrates and a purchased maintenance ration. Maximum and minimum daily intakes of dry matter and maximum daily rations of certain bulk feeds were specified for each month. Production requirements of starch equivalent and protein equivalent varied according to milk yield, in each month. The function being maximized was the total value of output—milk plus calves plus cull cows minus herd replacements and feed input costs.

TABLE 12

Optimal Feed Inputs with Variable Forage Crop Yields for April and October Calvers

Inputs/outputs	Month of calving	
	April	October
Margin per cow (£) (a)	113·5	118·4
Forage acres	0·98	1·04
Short term leys (acres)	0·75	0·84
Kale after leys (acres) (b)	0·23	0·20
Value of milk output	145·5	164·0
Calf value less replacement cost	10·0	8·0
Concentrates cwt. (c)	0	7·0
£ (c)	0	9·5

(a) Margin=Milk Value plus calf value less net cow replacement cost less concentrate cost less variable forage cost and opportunity cost of land used for forage production.

(b) Kale grown on land occupied by leys until June.

(c) Excludes steaming up.

The optimum feeding patterns and margins per cow for October and April calvers is set out in Table 12.

In order to modify the assumption of average forage yields it is necessary to select a suitable strategy to be followed to deal with surpluses and deficits. The authors assume that surpluses and deficits cannot be carried over from year to year, that forage cannot be bought and sold, but the surplus/deficit situation is entirely adjusted on concentrates with no additional output from the concentrates in the deficit situation. The linear programme was run for a given range of forage yields and, having determined the expected margin at specific yield levels, the loss/gain value is determined by applying the probability of each yield to the gain or loss. At the lowest yield levels considered the losses were £17 per cow for April calvers and £11·5 per cow for October calvers. At above average yields the gain was assumed to be zero because forage would not be substituted for concentrates. The average expected 'gain/loss value' was £3·0 per cow for April calvers and £1·7 for October calvers and therefore the *average* expected margins shown in Table 5 would be reduced by those amounts.

The results of this study seem to substantiate the conclusion that the risks from April calving and reliance on forage for production are higher than from autumn calving with a lesser reliance on forage, and a greater reliance on concentrates. Alternative policies to improve on the linear programme solution selected by the authors intuitively were unable to make any improvement on the original policy for April calvers whereas a reduction in forage acreage by 10 per cent did improve the average situation for October calvers.

With perhaps the exception of the linear programme study, most of the studies summarized in this section have tended to show how farms, in making better use of resources in milk production, have had to expand the number of cows in the herd. Technical innovations of a capital intensive nature seem to have reinforced this process, as has been seen especially by the study of the effect of increasing sophistication in the milking and handling of cows with the spread in particular of bulk tanks and in the increased use of tower silos for silage. Very small units cannot possibly justify expenditure on such equipment and relatively larger ones have to expand to achieve any possible economies in the use of resources that they offer. Nevertheless, the single study of the overall capital input in the expansion process that has so far been made suggested that, on average, the investment involved was just covered by the rate of return and it follows that some farms were spending more than might appear to be economically justifiable. This would suggest that there is not only greater need in more areas for studies by economists on the capital development of dairy farming but also greater need for discussion between farmers and their advisers of the problems involved.

4. Results of Other Dairy Research Projects

THE research period covered in this report is memorable for a number of reasons. The country suffered from a severe adverse balance of payments position and attention was given to the possible contribution of farming to our food supplies. It inevitably raised the question of increasing domestic beef supplies from our dairy herd and this in turn triggered off renewed interest in the seasonal pattern of milk production. Furthermore an outbreak of foot and mouth disease of unprecedented severity in this country also raised some fundamental problems. All these items have received attention and reports on certain aspects are summarized below. In addition the perennial topic of milk supply response receives attention and an analysis of milk transport costs is also presented.

INCREASED BEEF SUPPLIES

A report by Walker and Gardner (17) entitled *Beef from the Dairy Herd* highlights the different possibilities of increasing beef production from the dairy herd, attempts an assessment of by how much it can be increased and identifies and examines some of the implications of an increase. It also recognizes some of the difficulties in estimating future demand levels for beef.

Larger supplies of meat from the dairy herd may be obtained by changing or improving performance from the existing dairy breeding herd and/or by increasing the size of the dairy herd but with minimal changes in existing methods of management. The former might involve increasing the number of calves born, increasing the number of calves reared or finishing the fat animals at greater weights. The number of calves born is dependent on the calving interval, the incidence of twinning, and the extent to which calves are obtained from surplus heifers prior to slaughter. The number of calves reared can be increased by reducing calf mortality and reducing the numbers slaughtered for veal. In both cases the suitability of calves for rearing to beef weights needs to be ascertained. Increasing the size of the dairy herd can be achieved either by retaining cows which would otherwise be culled or by saving heifers which would otherwise have been fattened but in both cases there would be a temporary reduction in beef supplies.

The authors recognize that the calves of some breeds would be unsuitable for beef. They also assume that 'if the calvings equal the cow population (allowing for some culls calving as well as all replacement heifers), if 6·5 per cent of those born fail to survive to beef weights, if 25 per cent of the herd is replaced annually, and if 500,000 calves are unsutiable for rearing, then the potential number of dairy calves for beef each year is roughly 1·7 million – as follows:

Dairy herd (cows) = calves born		3,200,000
Calf deaths at 6·5 per cent	208,000	
Replacements at 25 per cent	800,000	
Unsuitable for beef	500,000	1,508,000
Calves available and suitable for rearing to beef		1,692,000

The calculations can be presented in a formula, into which different values may be inserted as necessary, appropriate on the assumption that national herd size does not change. Thus if

C = the calving index (12 months = 1·0; 15 months = 0·8)
α = the proportion of culls not calving
R = the replacement rate
L = the proportion of live births
S = the proportion of calves surviving

then the calves available for beef, expressed as a proportion of the dairy herd is given by the expression

$$[C\,(1-\alpha\,R)+R]\,LS-R$$

Hence if $C=0{\cdot}87$, $\alpha=0{\cdot}80$, $R=0{\cdot}25$, $L=0{\cdot}96$ and $S=0{\cdot}93$ then the expression would yield a value of 0·59. Applied to a cow population of 3·2 millions, this means, 1,888,000 calves available for beef.' A deduction for unsuitable calves gives the possible number of calves for beef production.

Improvements in the factors mentioned as well as increasing herd size would take time and most would be unlikely to have a measurable impact on beef supplies in under three years or more. The authors examine the time involved as well as the possible changes in quality with different methods of achieving beef expansion. When food is being processed on an increasing scale 'so that its original nature is masked from the retail consumer if not radically altered, it may be superfluous to draw attention to marginal or temporary changes in quality. Perhaps the logical conclusion to draw from the development of processing is that cattle, as a source of "beef", will themselves become superfluous'.

The authors acknowledge the fact that there are several methods of increasing beef supplies, but that some, such as reducing mortality, are not likely to make much impact. They indicate that an improvement in the calving index from 400 days to 382 days would result in an extra 100,000 calves annually, equivalent to a potential 25,000 tons of beef. A further 70,000 tons might be obtained from calves taken from heifers prior to slaughter, together with a contribution through the heavier weights at which the heifers are killed. Although these methods can result in substantially greater supplies the authors suggest that increasing the number of dairy cows is the most straightforward. All methods involve the use of additional resources, in particular feed, labour and buildings.

A 1½ per cent increase in the size of the dairy herd would be needed to produce an additional 10,000 tons of beef. 'If the dairy herd were eventually to be expanded by 5,000,000 cows this would imply the transfer of some 1¼ million acres of land from other (presumably arable) use. In terms of cereals foregone this would seem like a policy of importing nearly two million tons of wheat instead of 100,000 tons of beef—at little advantage in foreign exchange'. The use of additional fertilizers might reduce the land needed for dairy herd expansion but there would still be an annual cost of resources in buildings, feed, fertilizers and miscellaneous items of about £150 per cow. 'If five cows need to be added to increase meat supplies by one ton the cost of extra resources used to produce an extra ton of beef would be some £650'.

There seems little incentive to expand the size of the dairy herd merely on the basis of better beef prices. Indeed past increases have been in response to increases in milk prices, and this method is most likely to persuade dairy farmers to expand in the future. However, with such an expansion it would still be necessary to ensure that extra stock were reared and fattened for beef possibly by increasing calf subsidies. It might also be possible to encourage expansion by further provision of the capital necessary to provide extra buildings.

The authors conclude their report with a discussion of the demand prospects for beef. They suggest 'increases in annual beef requirements of the order of 36,000 tons to 73,000 tons at the end of a five year period'. This is considerably smaller than the increased production examined in the N.E.D.C. report on *Agriculture's Import Saving Role*, which was concerned with replacement of imports by domestic production. The extent to which an expansion of beef is justified depends on a number of factors, such as availability of supplies, availability of other meats, as well as the costs of various alternatives.

With regard to availability of supplies, the report mentions the increasing beef consumption levels in such countries as Italy and Spain, as well as the rapidly increasing imports into the U.S.A. in recent years, but on the whole it finds that beef production has kept pace with requirements and that there is no immediate prospect of a shortage of beef which would warrant the introduction of expensive measures to provide alternative supplies. It also states that 'given some flexibility in consumer demand as between meats, if necessary, there would seem little evidence to indicate the supply of meat to the United Kingdom failing to match requirements, in the short term being considered'.

With regard to costs, there is obvious difficulty in adjusting production to the point where marginal costs equal marginal returns. Furthermore, returns are influenced by deficiency payments and production may not therefore reflect consumer preferences. With substantial adjustments in production of beef, marginal costs would change, and could well further distort the marginal cost and retail price ratio. Since the income elasticity of demand for beef is lower than for other meats, a massive programme of beef expansion could run into the difficult situation of marginal costs becoming more and more divorced from retail prices.

It is clear then that within the United Kingdom considerable distortion can be brought about by the different measures to increase profitability of different commodities. Similar devices of protection and subsidy have similar effects on the international scene, and can move production and trade still further from the allocation under comparative cost advantage.

In addition to the detailed discussion of prospects for additional beef from the dairy herd the report presents a statistical appendix on the dairy and beef cattle industry in the United Kingdom. This includes cattle population figures, estimated casualties, numbers slaughtered, as well as information on supplies.

A contribution from B. E. Hill (18) on *Calf Supplies in the United Kingdom* adds further information on the possible expansion of beef production. The report emphasizes that one of the major determinants of scale of beef production is the supply of calves. Some data on the position over the 10 year period 1957 to 1966 are set out in Table 13.

TABLE 13

Calf Supplies in the United Kingdom

Year	(1) Potential calf supply (cows and heifers in milk and in calf)	(2) Calves reared (cattle less than 1 year old at following June census)	(3) Calves slaughtered	(4) Shortfall in calves reared and slaughtered from potential	(5) Shortfall in potential calf supply (col. 4) in per cent of col. 1
			thousands		per cent
1957	4,725	2,556	877	1,292	27·3
1958	4,648	2,735	642	1,271	27·3
1959	4,665	2,836	693	1,136	24·4
1960	4,836	2,772	917	1,147	23·7
1961	4,981	2,869	910	1,202	24·1
1962	5,070	2,923	821	1,326	26·2
1963	5,002	3,038	614	1,350	27·0
1964	4,924	3,383	407	1,134	23·0
1965	4,964	3,447	415	1,102	22·2
1966	5,020	3,361	571	1,088	21·7

Source: Agricultural Statistics and Output and Utilisation Series, M.A.F.F.

Hill assumes that the number of cows and heifers in the national herd represents the potential supply of calves, and proceeds to explain the shortfall between this potential and the number of calves reared and slaughtered. The shortfall can be explained by

(*a*) an under-estimate of cattle returned as less than one year which represents numbers reared.

(*b*) Some dairy cows recorded at June are culled without calving.

(*c*) The remaining shortfall is caused by mortality, abortions, still births and a calving interval in excess of 12 months.

The variation from year to year in the proportion of calves slaughtered is noted and Hill tries to explain this in terms of calf prices and calf subsidy. He derives an equation which gives a close fit between the 'expected 'and 'actual' values but only by omitting calf subsidy. He concludes that 'in recent years the number of calves reared has been 30 to 46 per cent less than is theoretically possible. ... Calf wastage should be reduced in time through improved standards of stockmanship. Calf slaughtering might be dealt with in the more immediate future by appropriate government policies. In particular, since calf prices appear to be more important than calf subsidy in influencing the proportion of calves reared, there appears to be a good case for removing this subsidy and giving an equivalent increase in the guaranteed price for fat cattle.'

SEASONAL PATTERN OF MILK PRODUCTION

The interest in beef production from the dairy herd which has been engendered by the Neddy report on *Agriculture's Import Saving Role* and the Selective Expansion Programme which followed it, also gives rise to a further interest in the seasonality of milk supplies. If the dairy herd is to be expanded for the purpose of producing more beef then it would seem logical to calve the cows in the spring so that the additional milk ensuing for manufacture is produced as cheaply as possible from summer grass*.

In the 1950s and 1960s as a whole it can be claimed that there was a change in the seasonal pattern of milk production towards slightly more summer milk. The basic evidence for this claim is the change in the position of the trough rather than any relative increase in the peak. In the early fifties the trough occurred most frequently in the autumn—usually September. In the sixties, on the other hand, it occurred most frequently in November and December. It is reasonable to assume from this that 'summer' production has increased with production in the later summer months—particularly August and September—tending to fill up and to flatten the seasonal curve of production. At the same time it seems that winter production has fallen *relatively* because the seasonal indices for November and December have declined.

These movements in milk output are not surprising in view of the changes in the Census data on calvings and the proportion of the dairy herd in milk and dry in the September and December quarters. For instance the proportion of dairy cows dry in the September return has tended to fall whilst the proportion dry in the December return has increased. Similarly the relative number of calvings in the September–November period has decreased whilst those in the December–February quarter have increased. It is questionable whether these changes in seasonality will continue, without further stimulus, into the seventies but they have certainly taken place in the fifties and sixties.

The measurement of seasonal changes in output in the research period under review has received attention in M.M.B. reports (4 and 5). Over a short period the changes in the seasonal pattern of output described above are almost undetectable. The M.M.B. report *Changes in Output 1963 to 1967* (5) contains a chapter which demonstrates that for individual producers extreme instability of seasonal patterns of production exist from one year to the next. It is, of course, realized that the seasonal patterns of production by individual producers are affected by factors unconnected with their seasonality plan. In view of this, the M.M.B. used a 'trend adjusted' measure of seasonality expressing the proportion of winter milk (October–March) as a percentage of the average of the preceding summer and following six months. This stabilized the pattern somewhat and led to certain interesting conclusions. Analysis by seasonality group and producer size group showed a very marked tendency for there to be greater stability in seasonal production amongst the larger size groups of producers. Similarly, the more specialized producers had a more stable seasonality pattern. It may be a reasonable inference that the larger and the more specialized producers have more definite seasonal plans of production than the smaller and less specialized producers and hence, if a policy of change in one direction or another is to be successful, it is these producers who will have to be persuaded to make the necessary changes.

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* *Agriculture's Import Saving Role p.* 70

An additional contribution to the subject of patterns of milk production comes from Cook and Upton (19) of Reading University in a paper entitled *The Phasing of Milk Production for Maximum Profitability*. The changing patterns of milk prices over the past 10 years are illustrated and attention drawn to the fact that production patterns have not responded very much. The authors suggest that 'the majority of farmers either still consider that a fairly high proportion of winter-produced milk pays them, or more simply, they may turn their backs against "change", with its inevitable costs'. It may also result from 'the diversity of managerial, physical and economic factors which influence the profitability of milk production in different farm situations'. In view of the complicated nature of problems of seasonal milk production patterns, this study concentrates on a consideration of the financial implications of certain related sets of calving patterns, lactation curves, yield levels, milk potential from bulk foods and price considerations. The study is based partly on detailed records of individual cow performances on one particular farm and partly on synthetic data for the construction of model situations.

The study refers to the limitations of inter-herd comparisons because of differences in management, stockmanship and environmental factors. By restricting the analysis to one farm, these variations are eliminated and the interplay within an individual herd and between individual cows of such important variables as date of calving, the timing and duration of the dry period, annual yield per cow and the state and duration of individual lactation curves in relation to potential production from bulk foods are expressed. 'It is strictly the interaction of these important factors in relation to a common feeding policy and to a given set of monthly milk prices (prevailing in any one year) which this study endeavours to explore'.

By concentrating on performance on one individual farm the authors have undoubtedly eliminated a number of variables which might have made interpretation difficult. Furthermore, the study related to a four-year period, and covered 439 separate calvings. Nevertheless, it was still found that the paucity of the data severely qualified the conclusions reached. For instance, preliminary analyses suggested that the highest mean values for margins over concentrates were evident in the case of May and June calvers. Further scrutiny of the data, however, revealed that on average the spring calving cows were in later lactations than those in the winter calving group and since yields improve after first lactations, this may well be the reason for the 'margin over concentrates' advantage of May and June calvers. The presentation of the data by lactation did overcome this to some extent but resulted in some categories being severely under-represented and this weakness induced the authors to pursue an alternative method of examining the problem. This involved four different levels of performance from bulk foods and also a set of assumptions on yield according to lactation number and calving period. These assumptions are set out in Tables 14 and 15.

TABLE 14

Distribution of Potential Gallons from Bulk by 13 four-weekly Periods

Period	Dates	Farm A		Farm B	
		'LOW' (gal)	'HIGH' (gal)	'LOW' (gal)	'HIGH' (gal)
1	Apr. 1 – Apr. 28	76	101½	140	140
2	Apr. 29 – May 26	112	154	140	140
3	May 27 – Jun. 23	112	154	102	124
4	Jun. 24 – Jul. 21	112	154	67	95
5	Jul. 22 – Aug. 18	112	154	56	70
6	Aug. 19 – Sep. 15	104½	118	45	45
7	Sep. 16 – Oct. 13	70	70	28	28
8	Oct. 14 – Nov. 10	70	70	28	28
9	Nov. 11 – Dec. 8	70	70	28	28
10	Dec. 9 – Jan. 5	61½	61	28	28
11	Jan. 6 – Feb. 2	56	56	28	28
12	Feb. 3 – Mar. 2	56	56	28	28
13	Mar. 3 – Mar. 30	56	56	28	28
	Total	1,068	1,274½	746	810

TABLE 15

Classification of Standardized Yields by Calving Period and Lactation Number

Lactation No.	Calving Period												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	811	803	803	802	823	836	846	869	888	876	881	852	832
2	835	827	825	823	841	853	861	883	903	857	873	876	855
3	854	846	843	841	831	864	870	877	912	859	885	891	873

All lactations are standardized at 44 weeks.

In addition each yield was adjusted downwards by 10 per cent and upwards by 10 and 20 per cent and a calving interval of 365 days assumed.

The margins over concentrates are given for a number of combinations. The range in margins over concentrates was found to be greatest when the bulk contribution was lowest and where the yield per cow was highest. Thus the analysis showed that, with milk potential from bulky foods of 746 gallons and yields 20 per cent over normal, the average variation in margin over concentrates was £23, whereas with bulk potential of 1,275 gallons and yields 10 per cent below normal, the variation was only £10 per cow. These figures 'clearly confirm that it is more important to maintain cows at a particular phase when the bulk contribution is low than when it is high'. This has induced the authors to extend the analysis to a 13 month calving interval and to calculate margins for three consecutive four-weekly periods to take account of cows taking longer periods between calving. They conclude that on this basis calving around mid-November has advantages. Firstly, it is the period which gives the most consistently high margins over concentrates for the 365 day calving index and secondly, for the 13 month calving index the total margin for the three lactations does not show a significant decrease from the maximum.

In the particular situations examined in this study it would seem that autumn calving still has attractions, but there are a number of factors which need to be examined on any particular farm. These would include the cost of changing over to an extreme production pattern, the impact of bulk tank collection, the pattern of milk and calf prices and the impact of different feeding costs. The study does, however, highlight the problems involved in coming to appropriate decisions.

IMPLICATIONS OF THE FOOT AND MOUTH DISEASE EPIDEMIC

In a contribution on the financial repercussions of the 1967/68 foot and mouth disease epidemic, Thomas and Stewart (20) of Manchester University draw attention to the combination of factors which contributed to the particular severity of this outbreak. For instance, the epidemic occurred in the most densely stocked regions of the country, weather conditions at the time favoured the spread of the disease and the commercial nature of modern farming has increased the contacts between farms. The direct and indirect costs of the epidemic to the nation were tremendous, and are estimated at 'well above the £35 million paid in compensation for slaughtered animals and for their disposal, but probably a good deal below the £150 million which has been suggested in some quarters'.

The authors present information derived from a random sample of 35 farms in Cheshire that had suffered foot and mouth disease. They are reasonably satisfied that this sample reflects the experience of all farmers who suffered from the ravages of the disease. Their computations involved, on the one hand, the summation of compensation for stock slaughter, any insurance payments and other receipts, such as payments for disposal of stock or government grants for ploughing and for delayed restocking and, on the other hand, the costs involved because of loss of revenue from livestock less any avoidable costs, such as for purchased feed and so on, and also less the value of crops grown. The difference, representing the loss of income until restocking was complete, has to be added to the costs of replacing the livestock lost. In the event, only the results of 24 farmers were available because some farmers either retired or introduced major changes in their farming system. The average position in the sub-sample is shown in Table 16.

TABLE 16

Average Gains and Losses from Foot and Mouth Disease on 24 Cheshire Dairy Farms

	Per farm		Per 100 livestock acres*	
	£	£	£	£
Compensation	12,755		8,919	
Insurance	1,656		1,158	
Other receipts	394	14,805	276	10,352
Deduct				
Net loss of income	2,984		2,128	
Less grants	304	2,680	212	1,916
Net capital available for stock replacement		12,125		8,436
Cost of new stock		10,918		7,634
Net surplus		1,207		802

* Livestock acres = acres of grass, forage crops and cereals used for livestock (Average 143).

Within this average picture, there was considerable variation from farm to farm and this is shown in Table 17.

TABLE 17

Distribution of Surpluses and Deficits per 'Livestock Acre'

Difference between losses and compensation		Including insurance payments number of cases	Excluding insurance payments number of cases
Surplus	£60 and over	2	—
	£40 to £60	2	1
	£20 to £40	3	2
	under £20	9	6
Deficit	under £20	4	10
	£20 to £40	3	3
	£40 to £60	—	1
	£60 and over	1	1

There were a number of reasons for this variation. For instance, the date of the outbreak was important, because the early outbreaks were usually in areas where restrictions were late in being lifted and, therefore, the loss of income was suffered over a longer period. Furthermore, compensation paid in the early stages was lower since valuations were related to market values which did not immediately reflect shortages—later on compensation was more generous. The cost of replacements also varied considerably, with farmers purchasing at the peak of restocking having to pay higher prices. The adaptability of farmers was also important in determining the variation from the average cost. Some farmers, in the early stages of the epidemic, quickly changed their farming systems and others took jobs outside their farms, so that losses were minimized, whereas a number of farmers were shocked into inactivity and suffered heavily.

The losses due to the epidemic were by no means confined to infected farms, and some farmers who escaped the infection suffered in a variety of ways. For instance, taking longer routes to market, delaying the sale of marketable stock, interrupting the breeding programme, retaining cows which would otherwise have been culled and an inability to pursue normal purchase and sale of store animals, these and other factors involved farmers in considerable inconvenience and costs. Unfortunately, 'there is no compensation for unavoidable losses on uninfected farms . . . the problems of estimation and of administration would be daunting. There is no doubt, however, that the losses to the nation are substantial in a long epidemic and their incidence on particular farms is largely fortuitous. The question which has to be answered is whether there is any alternative method of control which would reduce these losses'. This paper manages to draw attention to many factors which at present fall outside the purview of the existing scheme for compensation.

MILK SUPPLY RESPONSE

Cason (21) has used data on supply response at the farm firm level to predict aggregate supply responses. In his *Supply Response in Milk Production* he applies the relevant methodology to a lowland area in South-West England and devises a total supply response for milk by aggregating supply response from typical farm types within the region.

The exercise was restricted to parishes with over 84 per cent of their acreage under grass and a sample of parishes was then selected at random to yield some 1,000 holdings. Farms of 20 acres and over from these randomly selected parishes were then stratified by farm size and a 10 per cent sample taken from this stratified population. The sample farms were visited and data collected on land area and allocation, labour, capital (net worth), livestock building capacity, livestock numbers and milk sales. Most other input/output data were obtained from secondary sources. In addition an attempt was made to obtain the farmer's estimate of his potential capital borrowing capacity, and his preference for certain types of dairy buildings in the event of expansion.

To reduce aggregation bias, the farms were then grouped according to whether land, labour or capital was the absolute restricting resource.

'Given the postulated increased levels in the technological efficiency of land and labour use and with given capital requirements for the expansion of buildings and herd numbers then one of the three resources land, labour or capital will ultimately limit the expansion of milk production on each farm'. The next stage was to allow for improved levels of technology and productivity and here past performances were used as a guide. On this basis, six benchmark farm groups were identified:

1. Land restraint with low labour productivity
2. Land restraint with high labour productivity
3. Labour restraint with low labour productivity
4. Labour restraint with high labour productivity
5. Capital restraint with low labour productivity
6. Capital restraint with high labour productivity.

'The weighted average level of resources of the farms within each group became the resource levels for the benchmark farms' but it was necessary to eliminate the transfer of (unusable) surplus resources between farms and to make provision for the use for alternative activities such as beef production. In this way Cason was able to identify the resource levels for the benchmark farm in the six groups and these were subsequently included in a linear programme.'Farm plans and milk supply were derived for different milk prices', and 'the programmed milk production for each benchmark farm was raised for each type group and then aggregated to give the total supply response for the regions'.

Somewhat surprisingly, 'the results, which are subject to the assumptions made in the study, suggest that there is little scope for increased production in response to an increase in the price of milk in predominantly milk producing grassland areas. Typical farm types, derived by grouping farms according to the resources estimated to ultimately restrict milk output, or according to resource ratios, gave very similar results'.

THE TRANSPORT OF MILK

In his report entitled *Some Problems in the Economics of Milk Transport*, Wynne (22) describes the ways in which improvements not only in the quality and in particular the keeping quality of milk, but also in the transport system, have transformed a whole series of local markets into a single national market for the product. Furthermore, technological changes and the emergence of large units with economies of scale are having an impact, and increasingly milk and other products are being produced in areas of favourable natural conditions and less in areas where the main advantage has been proximity to the market.

In spite of rapid improvements in transport and keeping quality, milk still has disadvantages of bulkiness and of perishability. Nevertheless, the areas of heavy production are remote from the main markets, and transport from surplus to deficit areas still involves substantial costs. To examine these, a model based on the counties in England and Wales has been devised for the national milk market, each county being regarded as a single production and single consumption unit. The requirement of liquid milk for each unit has been assumed as liquid milk consumption levels plus 20 per cent, and on this basis counties have been classified into those with surpluses, those with deficits, and those that are self-sufficient. Map 2 shows the position on this basis of classification.

It was assumed that all milk was collected from farms and delivered either to a local dairy for retail delivery or to a depot prior to being taken to a market outside the county boundary. Milk consumed within the county of origin would bear the regional transport deduction, whereas milk for shipment outside would bear the local charge plus a further transport charge between depot and the urban dairy. The costs and routes for inter-county transport were assessed and analysed by linear programming techniques, using the mileage and costs calulated from the Board's contract rates for medium tankers. Table 18 and Map 3 show that relatively little milk is required to travel long distances. Only 61 million gallons were taken more than 125 miles and none exceeded 150 miles. The calculated mean cost of all inter-county transport is only 1·72 pence per gallon, with a total cost of £4,832,000. This may be compared with the actual transport deduction, covering transport from farms to first destination (dairy or depot) of all milk, of £8,688,000 in 1962/63.

The report contains an estimate of the transport costs if producers were charged the whole cost of sending milk to the urban markets (Map 4). Counties with milk deficits were charged regional transport deductions, and counties with surplus also charged the programmed costs of sending surplus to chosen deficit areas and surplus milk for manufacture, the highest rate found in the programming exercise above. On this basis the maximum regional difference of 1·8d. per gallon existed between North Wales and the South-East.

The possiblities of charging transport costs from farm to destination to the consumer are explored. The basis adopted for this exercise involves charging the regional transport deductions on milk consumed within the county, with milk transported further bearing the programmed costs but with costs now aggregated on the basis of destination of milk. The analysis has been done by county and the results are set out in Map 5. London and Middlesex have to carry a cost of 3·09 pence per gallon while Sussex has only 0·66 pence per gallon to pay.

Wynne ends his report by drawing attention to the changes that have occurred since the thirties—the diminishing importance of transport costs as a proportion of total costs, the emergence of the Board as the sole buyer of milk, and the declining number of distributors. 'There are, therefore, no serious practical difficulties about a reappraisal of the whole question of transport organization and finance, although some solutions might require legislative sanction'.

The main aim of the report is to show some of the complexities of the situation and to suggest directions in which progress might be effected. It stresses the importance of viewing the problems of the dairy industry within the wider context of farming in the United Kingdom. 'Within the confines of dairy farming it may appear desirable to minimize transport costs and

TABLE 18

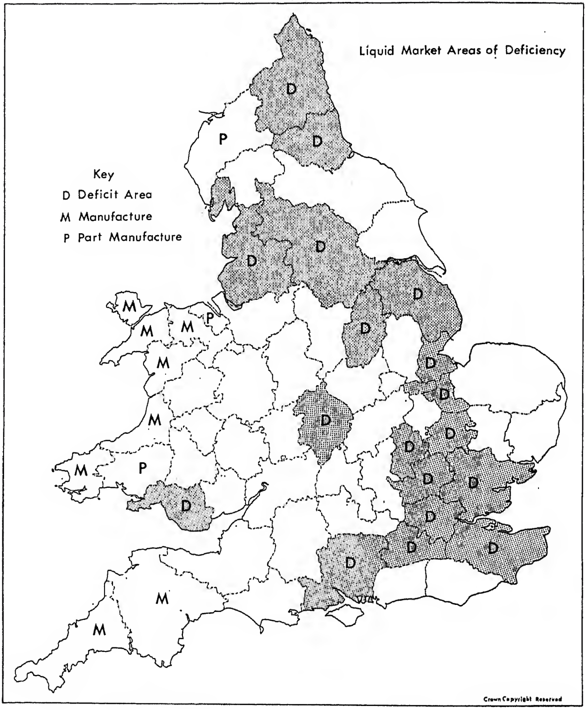
Programmed Transport of Liquid Milk

Source	Destination	Flow (100,000 gallons)	Cost per unit flow £	Total cost £
Berkshire	Surrey	33	512	16,896
Buckinghamshire	London	34	429	14,586
Cheshire	Lancashire	673	512	344,576
Cheshire	London	3	1,000	3,000
Cornwall	Manufacture	508	0	0
Cumberland	Northumberland	115	683	78,545
Cumberland	Manufacture	409	0	0
Derbyshire	Bedfordshire	32	771	24,672
Derbyshire	Cambridgeshire	37	771	28,527
Derbyshire	Lincs. Holland	17	704	11,968
Derbyshire	Lincs. Lindsey	14	683	9,562
Derbyshire	Nottinghamshire	140	429	60,060
Derbyshire	Yorks. West Riding	124	512	63,488
Devonshire	Manufacture	774	0	0
Dorset	Kent	153	1,000	153,000
Dorset	Surrey	428	771	329,988
Gloucestershire	London	206	771	158,826
Isle of Wight	Hampshire	41	429	17,589
Herefordshire	Bedfordshire	23	771	17,733
Herefordshire	London	114	917	104,538
Huntingdonshire	Isle of Ely	8	321	2,568
Leicestershire	Essex	91	771	70,161
Leicestershire	Soke of Peterboro.	17	512	8,704
Lincs. Kesteven	Lincs. Holland	5	321	4,815
Norfolk	Essex	180	704	126,720
Northamptonshire	Bedfordshire	31	429	13,299
Oxfordshire	London	75	575	43,125
Shropshire	Essex	263	1,000	263,000
Shropshire	Hertfordshire	23	917	21,091
Shropshire	Warwickshire	448	575	257,600
Somerset	Hampshire	2	704	1,408
Somerset	London	1,083	917	993,111
Staffordshire	Isle of Ely	13	771	10,023
Staffordshire	London	313	917	287,021
Staffordshire	Warwickshire	3	512	1,536
Suffolk	Essex	107	512	54,784
East Susex	Kent	71	512	36,352
West Sussex	Surrey	82	429	35,178
Westmorland	Durham (County)	233	512	119,296
Wiltshire	Kent	212	917	194,404
Wiltshire	London	414	704	291,456
Yorks. E. Riding	Lincs. Lindsey	22	575	12,650
Yorks. N. Riding	Durham (County)	45	512	23,040
Yorks. N. Riding	Yorks. W. Riding	268	575	154,100
Anglesey	Manufacture	70	0	0
Brecon	Glamorgan	33	429	14,157
Caernarvon	Manufacture	61	0	0
Cardigan	Manufacture	247	0	0
Carmarthen	Glamorgan	240	512	122,880
Carmarthen	Manufacture	275	0	0
Denbigh	Manufacture	214	0	0
Flint	Lancashire	52	575	29,900
Flint	Manufacture	100	0	0
Merioneth	Manufacture	29	0	0
Monmouth	London	10	917	9,170
Montgomery	Hertfordshire	188	1,000	188,000
Pembroke	Manufacture	346	0	0
Radnor	London	5	1,000	5,000

to encourage production near the markets. However, when we consider the national needs for greater cereal and meat production, the picture is different. A new equilibrium needs to be established between the different geographical regions. The national economy may gain more from concentrating milk production in the wetter regions than from continuing the present distribution of milk production. If this is true one may blame the conservatism of farmers in the East and Midlands for any excess of milk.

Finally, any solution should also look well into the future. Technical methods are changing, not only on the farms but also in the dairies and in the transport industry. We already have pipe-lines on the farms. Gas, oil, water and some other materials are sent much longer distances in pipes and milk may soon join the list. The question of delays through traffic congestion may mean that quite different routing than those suggested in this report would be more economic. Probably the whole of the analysis will appear naive to transport managers concerned with the day to day optimisation of transport routes, the satisfying of changing market demands for milk and making the most profitable use of the Ministry's various handling and transport allowance. However, little has been published about these problems and the broader approach to the national position may have some merit in high-lighting some of the problems of milk transport'.

Map 2



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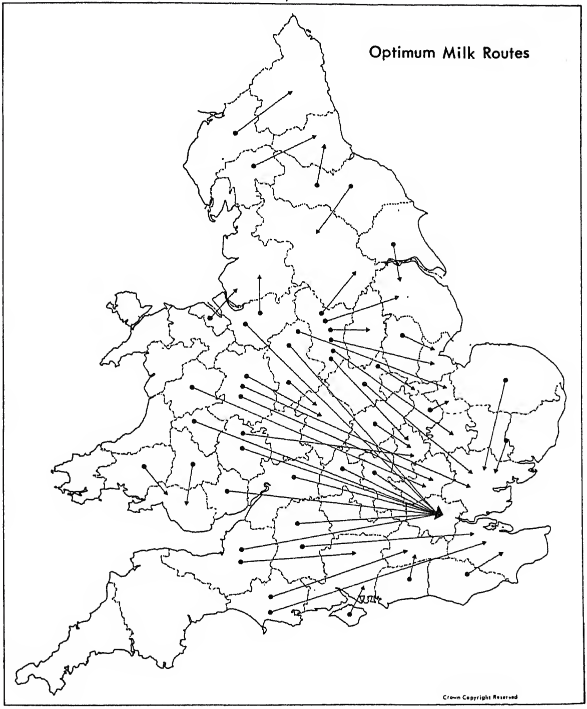
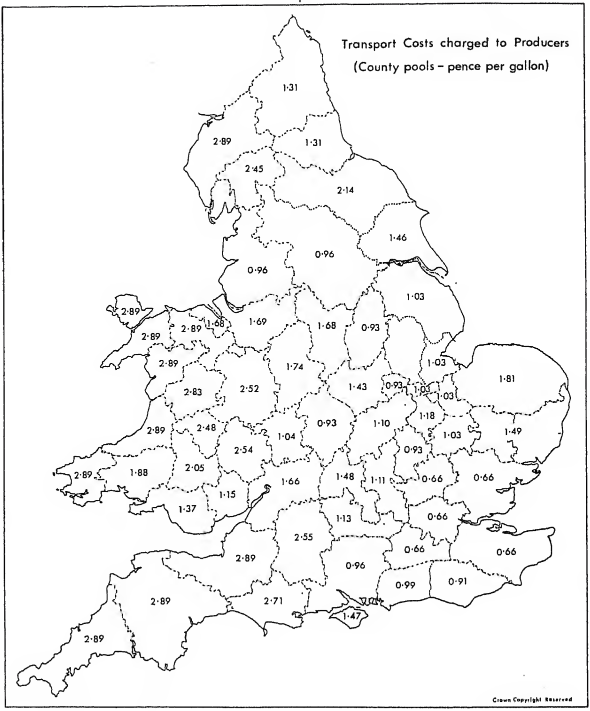
Map 3



Crown Copyright Reserved

Map 4



Transport Costs charged to Producers
(County pools – pence per gallon)

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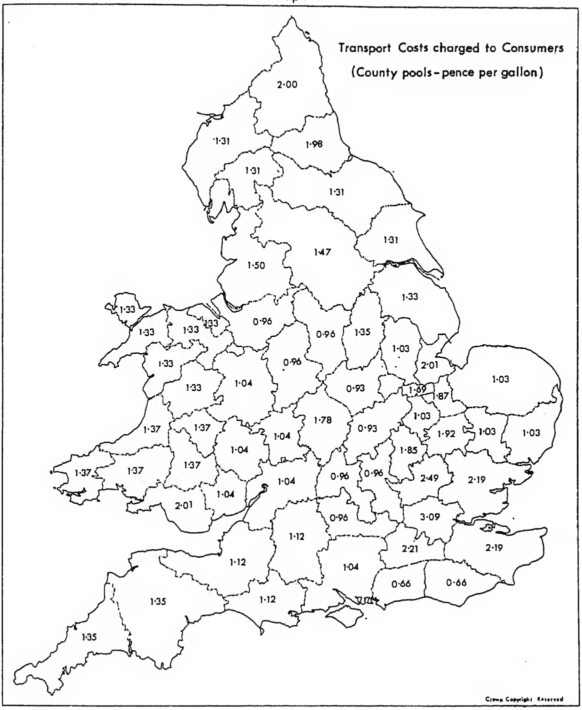
Map 5



Transport Costs charged to Consumers
(County pools - pence per gallon)

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A NATIONAL BUDGET FOR DAIRY FARMING

In a study under the title *A National Budget for Dairy Farming*, the Milk Marketing Board (23) have attempted to calculate the cost structure for milk production year by year. The study combines the use of price data for inputs year by year with aggregate data of output and inputs from general sources where these are available. When national statistics do not cover an input, reliance is placed upon projection of the Costings* themselves. The advantage is claimed for the technique that not only does it enable general data on income from milk production to be assessed, but that an estimate can be made during the current year and hence policy decisions can be taken in the light of the *current* situation rather than the immediate past. The M.M.B. point out that the use of this technique can be improved as data are built up and research extended on the basis of random field surveys.

Calculations have so far been made for the period 1965/66 to 1969/70. For the year 1969/70 the results show a slight rise in producers returns per cow compared with 1968/69 brought about by better calf returns. At the same time costs rose by more than returns and there was a decline in management and investment income per cow. Herd size rose between 1968/69 and 1969/70 from 33·3 to 34·9 cows per herd with the result that management and investment income *per herd* remained static. It is also shown that the value of farmer and wife labour rose between the two years which increased the level of *net farm income* per herd between the two years.

This study has been made possible through the use of random samples for field surveys since much of the aggregate data available from the Census and elsewhere on dairy cows, stocking rates etc., can be related to the field survey data and then used to project it. Like the Ministry's studies of *Farm Classification* discussed in Section 2, this work by the Board should be looked upon as one of a number of improvements in statistics available for dairy farming in the period of research under review.

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* The National Investigation into the Economics of Milk Production.

5. Methodological Aspects of Research

by A. J. Rayner

THIS section provides a review of the methodological aspects of the studies that have been summarized in the earlier sections. In addition, extensions of the work and the procedures used are suggested for some of the analyses. It will be apparent from the earlier sections that the methodological content of the articles under review varies quite considerably. As a consequence, some of the studies are examined in much greater detail than others within this section.

For ease of presentation, the articles have been collated under the following methodological headings.

(i) *Descriptive Studies.* The articles dealt with under this heading are those of: M.M.B. (8), M.M.B. (5), Beynon and Davies (7) and Winter, Evans and Johnson (9).

(ii) *Budget Studies.* The articles dealt with under this heading are those of: Beynon and Godsall (13), M.M.B. (23) and Thomas and Stewart (20).

(iii) *Technical Feasibility Study.* The article dealt with under this heading is that of Walker and Gardner (17).

(iv) *Markov Chain Study.* The article dealt with under this heading is that of Colman and Leech (10).

(v) *Linear Programming Studies.* The articles dealt with under this heading are those of: Gunn and Silvey (16), Cason (21) and Wynne (22).

(vi) *Regression Studies.* The articles dealt with under this heading are those of Hill (18), Williams and Jones (11), Wynne (12) and Bessell (15).

THE DESCRIPTIVE STUDIES

The general objective of a descriptive study is to provide a picture and assessment of changes occurring within an industry or a particular sector of an industry. The study commonly draws together background data on the industry and, by an examination of the data, describes the changes occurring and suggests reasons for these changes. Such a study also provides valuable source material for a more rigorous analysis. However, the technique content of a descriptive study is, by its nature, fairly slight, although statistical tests may occasionally be included to support hypotheses suggested by the data.

The study titled, *The Balance of Arable and Livestock Farming in British Agriculture*, M.M.B. (8), describes the extent to which grain crops were substituted for fodder crops, potatoes and grassland in British agriculture over the period 1955 to 1967. It also collates the changes that have occurred in the numbers and proportions of the various grazing livestock, in the use and productivity of grassland, in crop and livestock yields, in prices and in net farm income and management and investment income by type of farm.

The report discusses at some length the technical problem of measuring the productivity of grassland. After showing that the level of stocking density itself increased by 18 per cent in the 11 years 1955 to 1966 by dividing the total grassland acres by the number of grazing livestock units, it then attempts to show that there has been a very similar improvement in Utilized Starch Equivalent from grassland over the same period. Measures of grassland productivity are fraught with difficulties of data and assumption and many of these are spelt out in Appendices II and IV of this report. The calculation of U.S.E. from grassland by subtracting the S.E. values of concentrate from assumed total requirements leaves all the errors of measurement in the U.S.E. itself. However, the authors show in Appendix IV that even if the absolute level of U.S.E. is affected by this, the trend improvement is not.

A few points in the calculations may be noted. The calculation is limited to U.S.E. from grassland and does not attempt to assess the affects of changes in yields of hay and silage and the management of grazing. The energy requirement to graze grass is inevitably ignored in these calculations and they could be improved if the necessary experimental data were available. With the aid of more recent data from the Ministry's *Survey of Cattle Management and Feeding Practices in England and Wales 1966/67* (25) the authors no doubt will be able to make a number of refinements to their calculations.

Appendix III of the report presents a statistical analysis of changes in stocking rates in England and Wales. Firstly, a linear time trend is fitted to the annual data for the average stocking rate in England and Wales over the period 1955 to 1966. Secondly, the percentage change in stocking rate comparing 1966 with 1955 by region (ten regions in England and Wales are delineated) is correlated with changes in each of several separate variables (dairy cows in livestock units, beef cows in livestock units, beef stock in livestock units, sheep in livestock units, total grass acreage, permanent grass acreage and ley acreage). However, these two exercises are not, in the opinion of the reviewer, very enlightening. Firstly, whilst it is apparent that there has been a continuous decline in acres of grassland per livestock unit over the period it is by no means obvious that the underlying trend is a linear one. Consequently, it might be suggested that a non-linear trend also be fitted to the data and an investigation made into the constancy of the time rate of decline in acres per livestock unit from this non-linear trend. Secondly, even when the most appropriate time trend has been decided upon we do not have an explanation for the continuing improvement in stocking rates.* Nor would such an explanation seem to be provided by the simple correlation exercise contained within the report. For example, a significant correlation is found between improvements in regional stocking rate and the percentage increase in dairy cows. From this association, the report concludes, on page 9, that increasing herd size is a significant factor leading to an improvement in the stocking rate. However, one should beware of accepting a correlation as though it were an explanation without a preparatory theoretical rationale. For example, it is probable that dairy farmers who increase their usage of nitrogen per acre, increase both the number of cows and the stocking rate simultaneously and we, therefore, obtain a positive correlation between the latter two variables. On a more constructive note, one might suggest a multiple regression analysis of stocking rate combining both cross sectional (regional) data and time series (annual) data. Such an analysis would, however, require an initial, and perhaps quite considerable, theoretical specification.

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* Although we may have a useful predictive tool so long as the underlying causal variables keep trending over time.

The Structure of Dairy Farming in England and Wales: Changes in Milk Output 1963 to *1967*, M.M.B. (5), utilizes the permanent producer sample of 5,343 milk producers to provide a wealth of information on the changes in, and relationships between, the number, type, characteristics and output of milk producers in England and Wales between 1963 and 1967. Information is also provided on the relationship between output changes and farm characteristics, on the relationship between producers' intentions and performance and on changes in seasonality patterns. The M.M.B. should be congratulated on their sample selection procedure to judge by the lack of discrepancy between the raised sample estimates and the actual official statistics of sales of milk off farms and producer numbers. Given the success of their sampling technique, one may confidently view their data as illustrative of the general changes occurring within the industry as a whole. Much of the data is presented in the format of one and two-way contingency tables and conclusions are drawn as the result of inspection of these tables. The reviewer would have liked to see these conclusions substantiated by more use of the chi-square statistic—a statistic which appears to have been used only once in the report when null hypothesis of no association between producers' output plans and the actual levels of output was tested (Table 31, page 47/48). In fairness, it should be pointed out that the interested reader may perform his own chi-square tests after converting the percentages quoted within the cells of the tables into actual sample producer numbers*.

The two other studies included within this section—*Some Features of Dairy Farming in the Far West*, Beynon and Davies (7) and *Some Economic Aspects of Increasing Size of Dairy Herds and Modernising Dairy Systems in the Northern Region*, Winter, Evans and Johnson (9)—are sample survey studies of different sectors of the dairy industry. The study by Beynon and Davies provides a detailed record of certain aspects of dairy farming in Devon and Cornwall and draws conclusions which appertain to the dairy industry as a whole within these two counties. This being the case, the authors could have indicated whether their survey farms were representative of the region. One would also have liked the authors to compare the conditions of dairy farming within the two counties with the national picture of the dairy herd to highlight any regional differences which might exist and any consequent regional policy implications. Finally, as with the M.M.B. (5) report, the authors could have made use of the chi-square test in some instances to substantiate their conclusions.†

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* M. T. Jones (private communication) has pointed out to the reviewer that, as a result of the sample design, larger producers are over-represented in the permanent producer sample. Consequently, one would not want to use the sample numbers as cell numbers in the chi-square test in all situations. Instead, the raised (weighted) sample estimates would need to be used as cell numbers in certain situations.

† Although it should be noted that in several of their two way tables, some of the cells have less than five observations and amalgamation of cells would have been necessary before the application of the chi-square test statistic.

The report by Winter, Evans and Johnson (9) was orientated toward highlighting the changes that occur on farms following an increase in herd numbers and modernization of the dairy system. For this purpose, a sample of seventy-four dairy farmers, selected in the Northern region, was required to answer a detailed questionnaire. In addition, a budget was prepared using average data from the survey to check if the increase in herd size was generally profitable. Some regression analyses were attempted in the report but were unsuccessful. This is disappointing because it would be hoped that regression analysis would illuminate some of the reasons for increased profitability resulting from increased herd size. Various reasons for the lack of results are suggested by the authors; in addition, better results might have been obtained if more meaningful economic relationships had been tested. However, the report as a whole provides a valuable assessment of the changes and problems on the sample farms and leads to a better understanding of the modernization expansion process that is occurring within the dairy industry.

THE BUDGET STUDIES

The objective of a budget study is to assess the desirability of a particular project or policy by comparing the costs and benefits associated with the project. The type of costs and benefits taken into account are determined by the frame of reference of the study and consequently can vary widely. At one extreme, an adviser may draw up a budget for an individual farmer to determine if a change in the planning of the farm will add to the farmer's profits: at the other extreme, cost benefit analysis is used to assess the desirability of a particular public project or policy to the community as a whole and it involves the enumeration of a host of side effects.

The Impact of Tower Silos on Grass Conservation and Grain Storage, Beynon and Godsall (13), utilizes a sample of farmers in the Exeter province to draw up budgets on the costs and returns that were associated with investments in different types of tower silos by these farmers. The budgets concentrate, quite rightly, on the direct costs and returns associated with each type of silo; however, the possibilities of various indirect costs associated with technical difficulties and management factors are also mentioned. Presumably, there may also be non-profit benefits associated with the investment in tower silos? In summary, the study provides useful information to farmers and advisers about the costs and returns that result from an investment in the various forms of tower silos.

A National Budget for Dairy Farming, M.M.B. (23), presents a detailed cost and revenue budget for the national milk enterprise. Any criticism of such a study must centre on the cost/accounting procedures used and the present reviewer cedes this issue to the interested reader. However, one minor methodological suggestion for future issues might be made. In the 1969 report, net income figures from dairying over several years are presented. These income figures are measured in current prices; it would have been useful to have had net incomes presented in 'real' prices* or at constant prices so that one could see how the 'real' incomes of dairy farmers had changed over the time period involved.

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* i.e., deflated by the retail price index.

Farmers and Foot and Mouth Disease, Thomas and Stewart (20), attempts to determine the financial consequences of the 1967/68 foot and mouth epidemic on a sample of twenty-four farmers in Cheshire. Any methodological critique of this article, as of any other budgeting study, must settle on the accounting methods used to determine the relevant costs and benefits, once the terms of reference have been defined. In this instance, the framework of the budget to be derived was strictly confined to the financial losses of farmers whose farms were infected. The financial loss (or gain) of each farmer was measured over the time period between the initial infection and the return to a fully stocked farm. The authors consider whether the disease imposed costs on these farmers beyond the period considered—for example, because of a changed calving pattern—but conclude that these consequential losses were probably slight. In addition, the authors point out that there were consequential gains because the time period of non-operation allowed many of the farmers to substantially replan their businesses. The main virtue of the budgeting procedure in this investigation was that it picked out the variation in financial losses between farms and highlighted the causes of this variation.

THE TECHNICAL FEASIBILITY STUDY

The objective of a technical feasibility study is to ascertain what is possible—unlike an economic study which attempts to determine what is probable. The major policy use of the technical study thus lies in the check it provides on the feasibility of economic forecast.

The Walker and Gardner study (17), *Beef from the Dairy Herd*, attempts to determine the possibilities of expanding beef supplies from the dairy herd over a five year period. The facets considered are (i) expansion of the dairy herd using current production techniques, (ii) changes in some of the input/output coefficients of the average production process—for example, reduction of the calving interval, and (iii) the introduction of new technology via the adoption of a bred heifer system. Consequently, all possible methodological aspects are considered in the report and further discussion must centre on the technical assumptions made by the authors. In this connection, it is interesting to note that Hill (26) arrives at a quite different conclusion from Walker and Gardner about the possibilities of the bred heifer system. This point illustrates a major difficulty in using a technical feasibility study as a policy tool—it is not usually easy to obtain a consensus on the technical possibilities.

THE MARKOV CHAIN STUDY

It is generally recognized that successive observations of an economic time series often exhibit dependence. As a consequence, much time series regression analysis in agricultural economics specifies a dependence between the current value of the endogenous variable and its lagged value. Although such analysis is familiar, Markov Chain Analysis (the application of the Markov theory of stochastic processes) whereby the transition of a particular type of variable from one time period to the next is governed by a probabilistic structure is, as yet, generally unfamiliar. In fact, only recently via the pioneering work of Colman (27 and 10) has such analysis been used in agricultural economics in the U.K. However, the Markov Chain Model is potentially an extremely useful predictive tool. Consequently it was thought desirable to give a methodological introduction to Markov Chain Analysis in Appendix I to this review.

At this point, a brief verbal introduction would also seem desirable. Where Markov Chain Analysis is concerned with structural change, it is customary to define several size categories into which the firms under-study will fall. One of the categories will include those firms that are not within the industry but are potential entrants to the industry. Markov Chain Analysis then studies the transition of firms from one size class to another (including transitions into and out of the industry). The basis of the analysis is the assumption that the propensity of firms to move from one size group to another is characterized by a probability called the transition probability. More formally, the transition probability, p_{ij}, denotes the probability that a firm in size class i in one time period will transfer into size class j in the subsequent time period. The central point of analysis is the estimation of the complete set of transition probabilities that describe the movement of firms between the size classes. From this knowledge, and the assumption that the transition probabilities do not vary over time, predictions can then be made about the future structure of the industry.

Structural Change in the Dairy Industry in England and Wales, Colman and Leech (10), utilizes a first order Markov chain process to predict the structure of the dairy industry in 1970/71 and in 1975/76 from a knowledge of the structure during the years 1963 to 1967. The M.M.B.Permanent Producer Sample between 1963 and 1967 provided the basic data for the study and the sample was stratified by region and by output of milk. More specifically, each producer in this sample was assigned to an M.M.B. region and within each region, producers were classified by annual output of milk into six size classes. A further size class was also defined for each region to represent the case of no milk production in a particular year. This was necessary because producers both enter and leave the industry and, consequently, Colman and Leech needed to estimate the probability of a producer leaving (entering) the industry from (into) each of the six size groups. These size classes were then used to characterize the structure of the dairy industry in each region.

After classifying the producers for each year of the sample, Colman and Leech estimated a transition probability matrix for each region using the procedure defined by equation (8) in Appendix I. They encountered one serious problem in this estimation—namely, the problem of deciding on the number of potential entrants.* This was an important decision problem since the number chosen has an important influence on projections (see Stanton and Kettunen (28)). Colman and Leech decided that a large number of potential entrants characterizes the dairy industry.* They put forward two arguments for this choice—one theoretical and the other pragmatic. The theoretical argument follows that of Stanton and Kettunen who suggest that a large number of potential entrants be chosen for a competitive industry where there is freedom of entry. However, a counter argument has been put forward by Lee and Berry (29) who suggest that, if there are no barriers to entry, then all firms which desire to enter are able to do so and the number of potential entrants who do not enter the industry will be very small. If this argument is accepted, then the number of potential entrants in a competitive industry without barriers to entry is largely determined by the number observed to enter the industry rather than by conjecture about the number who decide not to enter. In a situation where one is dealing with stationary transition probabilities the latter argument may be more plausible since such transition probabilities implicitly assume that there will be no changes in the economic environment surrounding the industry under study. However, Colman and Leech also suggest that a large number of potential entrants is desirable because, if there are few individuals leaving the industry, 'the pool of potential entrants is soon reduced to an unreasonably low level'. In addition, they suggest that the selection of a high number of potential entrants has the desirable effect of reducing to a low figure the probability of re-entry. Even from our limited discussion we may, therefore, conclude that the problem of deciding upon the number of potential entrants is one that is subject to further investigation.

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* See, especially, Appendix I of the Report.

Having estimated the regional transition probability matrices, Colman and Leech went on to use these matrices to predict the structure within each region in 1970/71 and 1975/76 by means of equation (10) in Appendix I. The results of this prediction process have been summarized in earlier chapters and will not be repeated here. However, we should note the assumption underlying the predictions: that the calculated transition probabilities derived from the sample period (1963 to 1967) remain unchanged until 1975. Some assessment of the validity of this assumption is given by testing the constancy of the transition probabilities over the sample period.† Colman and Leech found that this assumption was clearly supported in eight out of the eleven regions and, therefore, that only in three regions were prediction errors likely to be serious. However, one must still remember that, even if the transition probabilities are reasonably stable over the sample period, they will only remain constant over the prediction period so long as 'no changes in the economic environment in the dairy industry occur' (Colman and Leech (10), p. 27). Clearly, the nearer the prediction period to the sample period, the more tenable is this assumption. In this sense, one would place more faith on the predictions of Colman and Leech for 1970/71 than for 1975/76. However, we may also look at these predictions from a different policy viewpoint. The predictions of Colman and Leech suggest what will happen to the output and structure of the dairy industry if governmental policy remains unchanged over the prediction period.* If these predictions do not comply with the objectives of governmental policy, then the implication is that policy instruments—for example, prices—must be altered in order that these objectives are achieved. Unfortunately, Markov Chain Analysis with stationary transition probabilities cannot suggest the necessary changes.

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* In fact the number of potential entrants in each region was defined as three times the number of active producers in the region in 1963.

† For the relevant test statistic see Colman and Leech (10) Appendix II.

At this stage in the review, a digression would seem useful. It will be observed from the discussion in the above paragraph that the assumption of stationary transition probabilities is a very demanding one. It is clear that the values of the various transition probabilities will be determined by various exogenous factors, such as prices and technology. Even if these factors are reasonably constant over the sample period, they may change over the prediction period. Furthermore, the longer the sample period, the greater is the possibility of change in these factors and the less likely are we to observe stationary transition probabilities.† This leads to the suggestion that, if possible, one should obtain the sample relevant to the analysis over a reasonably long time series, and perform quite a strict test for constancy of the transition probabilities. If the null hypothesis of constancy is rejected then the model should be modified to allow the transition probabilities to change as the exogenous factors change. Hallberg (30) has proposed a feasible method for incorporating a non-stationary assumption into the first-order Markov Chain Model. The essence of his proposition is to relate the transition probabilities to the exogenous factors through the use of restricted least squares. His article does in fact open up an exciting development in the possibilities of Markov Chain Analysis and hopefully, will lead to a wider use of Markov Chain Analysis than has so far occurred.

The possible applications and usefulness of Markov Chain Analysis will, however, be conditioned to a material extent by the quality and scope of the data available. Colman and Leech were fortunate in obtaining information from the M.M.B. from which they were able to observe actual transitions of individual farms throughout the sample period. The use of this data had the drawback on the other hand that they indicated size groups related to milk output rather than herd size. An alternative source of data about sizes of farms and enterprises, together with numerous other characteristics such as degree of specialization, is the Agricultural Census. The analyses presently made of census returns are confined, however, to classifications of holdings year by year according to various criteria, presenting annually a series of tables relating to that year only. The use of such data for Markov Chain purposes has to rely on a relatively unsatisfactory indirect method of estimating transitional probabilities. The way would be opened to a substantial improvement of both our insight into the processes of agricultural change and our powers of prediction if analysis of the census results were to pay more attention to movements of individual holdings between size groups, type of farming classes, etc., over periods of time. Such analysis would probably entail new computer procedures for recognizing holdings and collating returns from each holding over a number of years. Initially the desired analysis might have to be confined to samples of holdings. But any advance in the direction suggested would have the merit of developing the usefulness of census data to match the growing interest in structural change and methodology already available for describing or projecting it.

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* However, note that there is the implicit assumption that if changes in technology occur they will not affect the transition probabilities.

† For empirical evidence, see the study by Hallberg (30).

The reviewer concludes his comments on the Colman and Leech paper by noting their useful employment of the Markov Chain technique: he will be most interested to see how their predictions compare with the actual structure of the dairy industry in 1970/71 and 1975/76.

THE LINEAR PROGRAMMING STUDIES

A linear programming (L.P.) study may be defined as the analysis of a problem in which a linear function of a number of variables is to be maximized (or minimized) when these variables are subject to a number of constraints in the form of linear inequalities. In general, an L.P. study attempts to determine the optimal allocation of limited resources to fulfil a given objective: it is, therefore, basically a planning tool.

Profit Maximization in Grazing Livestock Enterprises, Gunn and Silvey, (16) discusses the selection of a feed policy for dairy cows which maximizes average, annual profits in a situation where forage yields vary from year to year. In particular, the authors show that if the optimal feed policy is identified by L.P. using average forage yields then the profit generated by the programme will be higher than the average profit which can, in fact, be achieved. This result arises because the extra costs incurred in years of below average yields are assumed to be greater than the benefits derived from years of above average yields. In fact, they assume that there are no financial benefits to be gained from above yields. This assumption implies that the loss/gain function relating profit variation to forage yield variation is discontinuous with below average profits occurring if forage yields are below average and average profits occurring if forage yields are average or above. In addition, because of the L.P. framework, negative deviations from average profit are assumed to be a linear function of the negative deviations from average forage yield.

However, one should not be too surprised at the derived conclusions since the authors are setting up the L.P. model on the basis of one criterion and evaluating it on another. Thus, the use of average forage yields in the L.P. model, where it is recognized at the outset that there is variability in forage yield from year to year, implies the assumption that the loss/gain function is uniformly linear in both the negative and positive segments. In other words, if average forage yield is used in a situation where forage yields are uncertain then the weights that are attached to the possible forage yields are such that the benefits of higher than average forage yields are assumed to exactly cancel out the costs of below average forage yields. Consequently, this is the implicit assumption embodied in the L.P. model set up by Gunn and Silvey, whereas in their evaluation procedure they assume that zero weight is attached to above average yields whilst positive weights are given to below average yields. Therefore, one might suggest that if, in fact, above average forage yields give zero benefits, the forage yield utilized in the L.P. model should not be the average yield. Rather, if the simple average yield is equal to z, above average yields should be set equal to z, and the average of this adjusted probability distribution of yields should be the one used in the model. Finally, one might suggest that the use of the simple average yield might be more reasonable in any practical application of L.P. even if the financial benefits of above average yields are zero. Thus, some non-financial benefits may be attached to above average yields because there is a greater possibility that the L.P. plan can be carried out in practice in such situations than in the situation where average yield occurs.

Supply Response in Milk Production, Cason, (21) attempts to predict the 1972 supply response pattern for milk from a lowland area in the South West Region by a variable price linear programming model.

Very briefly, the following sequence was carried out:

(i) Obtain a random sample of farms stratified by farm size.

(ii) Collect the necessary data on resource levels, etc., and estimate input/output coefficients for 1972 after allowing for technological change.

(iii) Group the sample farms according to the absolute restricting resource. This procedure was designed to minimize aggregation bias following the work of Sheehy and McAlexander (31) and Frick and Andrews (32). An alternative grouping procedure suggested by Day (33) was also experimented with.

(iv) Derive a benchmark farm for each group with resource levels for the benchmark farm defined as the weighted average resource levels of farms within the group.

(v) Set up a linear programme for each benchmark farm, with a profit maximizing objective, and subject the programme to variations in the milk price. This procedure gives a stepped milk supply curve for each farm and the output level at each price is raised to give the milk supply curve for each group of farms.

(vi) Aggregate the group supply curves to obtain the milk supply curve for the area.

(vii) Adjust certain input/output coefficients and resource constraints to show the possible effects of specification error.

On the whole, the results of the study are fairly disappointing since (a) the initial programmed production at current prices greatly underestimated current production and (b) changes in resource levels led to large changes in programmed output. However, perhaps we should not be too surprised that the L.P. approach has serious limitations as a predictive tool.* Firstly, linear programming is a static optimizing model whilst we have empirical evidence which indicates that production decisions are governed by dynamic considerations within a framework of risk and uncertainty. In addition, LP.. incorporates technological change as a once and for all change whereas in reality it is a continuing process and new technology is taken up by different farms at different rates. Consequently, L.P., which predicts what a group of farmers would do under the same technological environment and under a profit maximizing assumption without regard to considerations of uncertainty, cannot be expected to predict what farmers do. Secondly, there are serious practical problems associated with building an aggregate L.P. model.* In particular, there are the problems of (i) interdependence, (ii) changes in farm size and (iii) selection of representative farms and estimation of data. The problem of interdependence has two facets: firstly, a change in aggregate output may affect the cost structure of the individual benchmark farms and secondly, a change in an output price may lead to changes in the input/output coefficients of individual farms. A second factor which may affect the validity of the model, and which is difficult to allow for, is changing size of farm. The third problem has three components: sampling bias, specification bias and aggregation bias. It is clear that these biases cannot be eliminated, although procedures may be set out to minimize them. Of particular concern is specification bias—errors in the resource constraints, technical coefficients and prices—since this bias may be magnified through aggregation.

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* This assertion is not based solely on Cason's results: Sharples (34) reports that over 80 research studies on programming regional supply using benchwork farms have been published in the U.S.A. and that results have been, in general, disappointing.

However, perhaps we may conclude the review of Cason's report on a more constructive note. Whilst the predictive value of L.P. with respect to supply response would seem to be quite limited, there would still seem to be a useful role for such studies in short run supply analysis. The virtue of linear programming is that it focuses attention on resource constraints and it is, therefore, very useful in identifying the nature and magnitude of short run supply adjustment problems. In addition, one would suggest that the likely effects of policy changes should be analysed both at the aggregate level, using econometrics and aggregate data, and at the farm level utilizing L.P. studies of several representative farms. The information gained at the farm level would then prove valuable not only from the farm management point of view but also to assess and, possibly, adjust the aggregate estimates.

Some Problems in the Economics of Milk Transport, Wynne (22) sets up a transportation programming model to select an optimum pattern of inter-county milk movement in England and Wales. The transportation model has been described as a 'point trading' model—each area under consideration is represented by a single representative point and prices and quantities traded are determined to minimize total transhipment costs between these points, under the assumption of a fixed supply and demand at each point. Wynne chooses counties as the supply and demand areas for milk, with production in 1962/3 being taken as the fixed supply in each county and consumption data from 1961 being used to derive the fixed demand for liquid milk for each county.† The trading points are assumed to be the approximate mid-points of the counties. Surplus and deficit trading points are then identified and the equilibrium solution for the model found whereby the market is cleared at minimum transportation cost. The programmed inter-regional flows are then utilized to assess two alternative methods of charging for milk transport: namely, (i) transport costs charged to producers and (ii) transport costs charged to consumers. Method (i) leads to suggested county price differentials for milk on the supply side; method (ii) leads to suggested retail price differentials between counties.

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* These comments are adapted from those of Sharples (34)

† The liquid milk requirement for each county was, in fact, fixed at 20 per cent above the liquid milk consumption figure.

One of the basic difficulties in a transportation study of this kind is in defining the separate areas. Agricultural production uses land in a contiguous fashion and supply areas cannot usually be clearly delineated. A second difficulty lies in the choice of the basing points—again, they may not be immediately obvious; furthermore, the trading point for demand within an area may differ from the supply point. Thirdly, the results of the model are often quite sensitive to the decisions made about areas and trading points. No justification is made in Wynne's study for choosing counties as the relevant areas and for choosing mid-county points as the trading points. It is by no means clear to the reviewer that these are the 'natural' choices; indeed one would have thought that 'natural' basing points might be related to the existence of the main milk depots and urban concentrations within the counties. Consequently, one is unsure as to the usefulness of the conclusions drawn from the results although one sides with the use of an explicit formal model to arrive at the results. In addition, it does not seem valid to assume that demand and supply price elasticities for milk are negligible in all areas and, therefore, that the surplus and deficit figures are invariant to changes in regional price differentials.

THE REGRESSION STUDIES

Regression analysis—or Ordinary Least Squares (O.L.S.)—is a method of statistical inference which has been found very useful in the analysis of economic phenomena. In particular, it is used to quantify the stochastic relationships of economic theory in situations where the disturbance term is thought to have certain properties. It should be emphasized that the use of O.L.S. is not simply a matter of fitting a curve to some data; rather, its use lies in the application of measurement to theory. Consequently, our review in this section encompasses both a critique of the statistical methodology and a discussion of the theoretical models that have been set up in the various studies.

The studies by Williams and Jones (11), *Economic Relationships in Milk Production* and Wynne (12), *Sources of Increased Income from Milk Production* are reviewed concurrently, since both are concerned with feed input/milk output relationships and labour cost relationships in milk production. However, it should be noted at the outset that the Williams and Jones study utilizes cross-section data—the data provided by the *National Investigation into the Economics of Milk Production– 1965/66*—whilst the study by Wynne utilizes time series data—the average figures from the same source but from the years 1933/39 to 1961/62. The reports are examined under two headings:

(i) FEED INPUT/MILK OUTPUT RELATIONSHIPS

The first relationship examined by Williams and Jones is the standard production function for the dairy cow in which yield per cow is related to various feed inputs and certain 'nuisance' factors which shift the production function. More specifically, yield per cow is related to concentrates fed per cow (in cwt), grazing acres per cow, fodder input per cow (in cwt of D.M.), fertilizer cost per grazing acre (in £), the transpiration rate (in inches), land quality (defined using intercept dummy variables), seasonality (per cent winter milk), percentage dry cows and breed (defined using intercept dummy variables). In contrast, Wynne relates concentrate feed in lb per gallon to average milk yield per cow and a linear time trend. Whilst standard production theory underlies the Williams and Jones relationship, no theoretical justification is put forward for the Wynne study—it would appear to be a case of 'measurement without theory'. In fact, one suspects that the causal relationship in Wynne's study is the opposite to that specified: increased concentrate feeding per cow has a diminishing marginal product so that the level of concentrate feed per gallon is larger in the higher yielding herds.*

Whilst we can accept that the Williams and Jones production function study has a sound theoretical basis, several, fairly general, comments can be made upon their analysis. Firstly, both linear and double logarithmic relationships are specified despite the fact that they represent very different hypotheses as to the way in which milk yield responds to changes in the various feed inputs. However, there is both theoretical and empirical justification for (a) the assumption of diminishing marginal productivity and (b) the assumption of substitition between feed inputs. In general, the research worker benefits by using such *a priori* information; so that in this instance the linear formation could have been rejected at the outset. It should also be pointed out that one cannot choose between the two algebraic formulations on the basis of R^2. Thus the logarithmic form minimizes the mean squared *percentage* error while the arithmetic form minimizes the mean squared error. If the regressions are to be compared on the basis of R^2 then the predicted values must be converted to a common form, either logarithmic or linear, and the R^2 of the equation whose predicted values have been transformed should be recomputed. However, the reviewer would suggest that the choice between alternative functional forms should, in general, be made mainly on the basis of *a priori* information and *ex post* reasonableness, with R^2 comparisons (after adjustment) being a less important consideration. Secondly, one of the more important problems in any regression study is to obtain relevant measures of the independent variables. This is always a problem in a production function study where inputs which are not wholly homogeneous or perfect substitutes have to be aggregated into input classes. In this respect, one might criticize the measures of concentrates and fodder used by Williams and Jones. With both of these inputs, one might expect significant quality variations from farm to farm—for example, because some farmers purchase higher nutrient concentrates than others and because the nutritive content per lb of dry matter of bulk feeds varies. Consequently, the measures of the input variables used in the analysis might not adequately reflect the nutrient input to the production process which is what they are supposed to reflect.* One might suggest that market value—actual or imputed—would almost certainly have been a better measure of the concentrate input and possibly also of the bulk fodder input.† Thirdly, four variables—fertilizer cost per acre, grazing acres per cow, land quality and transpiration rate—are included to measure the nutrients available from grazing. The definition of fertilizer cost on a per acre basis rather than on a per cow basis can be queried since farmers may use fertilizer to increase stocking rates rather than to substitute for other feeds or increase milk yields. Finally, a comment can be made on the use of dummy variables in this analysis—the comment will only be brief at present as we shall return to the subject of the usage of dummy variables in the discussion of labour costs in milk production. Dummy variables for land quality and breed were only associated with the intercept term in the analysis although it is possible that the slope coefficients of the production functions could also vary over these qualitative factors—for example, the response of milk yield to extra concentrates or extra fodder might vary between breeds. Consequently, one can suggest that these hypotheses should have been investigated since not only are they interesting in their own right, but also because if correct, the parameter estimates that were obtained could be subject to specification bias. In particular, the coefficients of the intercept dummy variables may be seriously biased.‡

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* We might note in passing that a somewhat different specification of Wynne's model might have some theoretical justification: if one believes that farmers feed according to the 'textbook' rules of x lb of concentrate feed per gallon, then concentrate feed per cow might be determined by yield per cow. However, the direction of causation in this case would be in an opposite direction to the production function hypothesis and the reviewer would tend to prefer the latter hypothesis.

Having explored the dairy cow production function in some detail, Williams and Jones go on to analyse various other input/output relationships. In particular, four other dependent variables are considered—stocking density, output per forage acre, utilized starch equivalent per forage acre and margin over feed cost per forage acre. In so far as the framework of these relationships explaining these variables is similar to the framework of the production function relationship, the comments made above apply with equal force to these other input/output functions.

The appendix to Williams and Jones' paper questions the appropriateness of applying the standard unweighted linear regression analysis to the sample survey data in order to estimate the input/output relationships. An answer to the question is not easy since it involves a complex discussion of the sample selection procedure, the theoretical model specification and the possibility of heteroscedasticity. § In order to make some start toward answering the question within this review, let us assume that the input/output relationship was concerned with the cow as the unit of observation rather than the herd* and that the sample was fairly representative of the cow population. However, because data were unavailable on the milk yields and feed inputs of individual cows, the investigators were forced to use herd averages as the units of observation. Let us further assume that the variance of the disturbance term for the input/output relationship was constant across individual cows. It then follows that the variance of the disturbance associated with herd averages was not constant because herds are of different sizes.† In other words, the regression model applied to herd averages was subject to the problem of heteroscedasticity. In such a situation, although ordinary least squares provides unbiased estimators, it is an inefficient procedure (see Johnston *op. cit.*). A more efficient, and therefore preferable, procedure which yields unbiased estimators is a weighted least squares model. The appropriate weight to be attached to each group observation (herd average) is the number of observations (number of cows) contained within the group (herd). This type of weighted regression procedure has been widely used in budget analyses where the sample data are published in the form of grouped averages and the reader is referred to Prais and Aitchison (38), Cramer (39) and Haitovsky (40) for further details.

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* This observation implies that the analysis of Williams and Jones is subject to the statistical problem of 'errors in variables'. Consequently, their parameter estimates are liable to be biased although this should not lead us to reject the results of the study.

† Since the study utilizes cross-section data one may assume that most of the variation in prices paid (actual or imputed) per unit of an input reflects variations in the quality of the input. However, one would have to make allowance for the transportation cost element in some feed prices.

‡ The reader may be referred to Stewart and Rayner (35) for an example of the serious specification bias that can occur on intercept dummy variables where there has not been a prior rejection of the null hypothesis of equality of the slope coefficients across the qualitative factor.

§ Heteroscedasticity is the econometric term for the situation where the variance of the disturbance term of the regression cannot be assumed to be constant (see Johnston (36) pp. 207–211).

(ii) LABOUR IN MILK PRODUCTION

Both the Williams and Jones study and Wynne's study have made some analysis of the use of labour in milk production. Both find some evidence for the hypothesis that the average input of man hours per cow falls as herd size increases. Wynne uses time series data over the period 1948/9 to 1961/2 and regresses man hours per cow on a linear time trend (representing technological change) and the logarithm of average herd size. The coefficients of both variables are negative indicating that (a) technology has been labour saving and (b) the labour requirement per cow decreases as herd size increases. Wynne uses his equation to forecast labour requirements per cow for various herd size groups for 1965/6 and then compares his forecasts with the actual values for that year. For all herd size groups, the forecast values are below the actual values, the error ranging from 3 to 9 per cent. Wynne suggests that the forecast error results from the fact that the data for 1965/6 were obtained from a random sample whilst the data used in estimation were from a selected sample of dairy farmers who were more efficient than the average. Whilst this may be true, it may not be the sole reason for the prediction error—for example, the underlying trend may be non-linear or the equation may be mis-specified in some way. In addition, one would have liked to have seen the 95 per cent confidence intervals presented with the predictions.

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* If the theoretical model specification was concerned with the herd rather than the cow, then the line of attack on the problem will be somewhat different from that presented.

If the sample design is such that the sample, although efficient in terms of minimizing sample error, is unrepresentative, a weighted regression procedure is appropriate for estimation purposes. Such a procedure would assign a relatively low weight to individuals sampled with a relatively high frequency. The reader is referred to Klein (37) pp. 305–313 for a full discussion. Note that the major problem with respect to Williams and Jones' paper probably arises from the grouping of individuals rather than from the sample design.

† A proof is given in Appendix II.

Williams and Jones present a detailed cross-section analysis of labour requirements in dairying. Labour input in man hours per year is related to herd size, yield per cow and various qualitative factors using both linear and double logarithmic equations. The qualitative factors considered are place of housing (three classes), place of milking (four classes) and method of milking (four classes). The analysis of qualitative factors was carried out in two stages. Firstly, a restricted co-variance analysis testing for the influence of each class of each qualitative factor on the intercept term of the regression was carried out. It should be noted that this test was based on the *a priori* assumption that the slope co-efficients of the regression did not vary across the classes of the qualitative factors. This analysis indicated that the regression intercept varied according to which class of place of milking and which class of methods of milking was considered whilst the intercept effect of method of housing was non-significant. Secondly, the assumption of equality of the parameter of herd size across the classes of the qualitative factors was relaxed in equations relating labour input to herd size, milk yield, two classes of place of milking and three classes of method of milking. (Place of housing was not considered in this analysis). To carry out the analysis, dummy variables were defined so as to allow the intercept and slope parameter of herd size to vary across all the possible combinations of the two qualitative factors. In the linear equation, the non-significant variables were milk yield per cow, the intercept dummies and one of the slope dummies. Therefore, the results of this analysis conflict with the *a priori* assumption of the restricted co-variance analysis carried out previously. Consequently, these results generate little confidence in the inferences drawn from the co-variance analysis. However, in the logarithmic equation, three of the intercept dummies were significant and only one of the slope dummies was significant. However, the existence of multicollinearity between the intercept and slope dummies leads to large standard errors and tests of the significance of individual dummy variables may not be very useful. Rather, one would suggest that the F test procedure described below be used to determine which classes of the qualitative factor have an important influence on the regression coefficients. This procedure has the advantage that it is based solely upon the residual sum of squares from the regression and is unaffected by multicollinearity.

It should be apparent from the above discussion that the sequence of analysis carried out by Williams and Jones, whilst useful and instructive, has in fact been performed in the wrong order. Logically, one should first test for equality of slope coefficients across combinations of the classes of qualitative factors and only if this null hypothesis is not rejected should one look at intercept effects using a test which assumes that the slope co-efficients are unaffected by the qualitative factors. Furthermore, a more general comment may be made. It has been shown quite recently (Stewart and Rayner (35)) that either the dummy variable approach or the co-variance approach (and the comparable analyses of the Chow test and direct tests of restrictions) may be used to provide the relevant F test statistic of a null hypothesis concerning the influence of a qualitative factor (or factors) on the co-efficients of a regression model. In general, the dummy variable approach is computationally easier and more flexible: consequently, our further discussion is in terms of this type of analysis. To perform a test on the null hypothesis of equality of some or all parameters of a regression model across some or all classes of a qualitative factor (or combinations of qualitative factors), two regressions need to be performed. Firstly, dummy variables are included such that all the parameters of the model can vary across all classes of the qualitative factor,* (or all combinations of the qualitative factors)—this regression may be called the unrestricted regression. Secondly, a restricted set of dummy variables is included such that the null hypothesis is incorporated into the regression equation—this regression may be termed the restricted regression. If S is defined as the residual sum of squares from the unrestricted regression and S_* is the residual sum of squares from the restricted regression, then an appropriate test of the null hypothesis is given by:

$$F = \frac{(S_* - S)/g}{S/(n-pk)}$$

where g is the number of independent restrictions imposed by the null hypothesis, n is the total number of observations, p is the number of categories of the qualitative variable (or number of possible combinations of the qualitative factors) and k is the number of explanatory variables of the regression model (including the intercept). Furthermore, the use of this test lends itself to a logical sequence of testing for the influence of a qualitative factor or factors (for details, see Stewart and Rayner *op cit*) and is to be preferred to the type of test procedure carried out by Williams and Jones.

The above comments may give a rather unbalanced view of the paper by Williams and Jones. In general, their paper has successfully accomplished their objective of analysing in a rigorous manner the data obtained from the National Investigation into the Economics of Milk Production for 1965/6. From the methodological point of view, the reviewer would concur with their comment regarding the importance of checking conclusions drawn from tabulated results by statistical analysis and feels that they have made a constructive contribution in this direction.

Levels of Economic Performance in Milk Production, Bessell (15) uses regression analysis to investigate the influence of resource use on the profitability of milk production. Unfortunately, there is a noticeable lack of prior theoretical specification of the relationships involved in milk production. Consequently, it is not apparent that all the estimated statistical relationships are necessarily meaningful or free from serious specification error. For example, the core of the analysis is a set of relationships between forage acres per cow, concentrated feed per cow, units of nitrogen applied per forage acre, margin over feed and fertilizer costs per forage acre and yield per cow. Firstly, yield per cow is treated as exogenous to the system. Whilst we accept that the potential yield per cow is determined by genetic characteristics, can we accept that actual yield per cow is uninfluenced by the quantity and quality of available feed? Secondly, the second equation to be estimated in the system related concentrate feeding to milk yield and forage acres per cow. However, it was previously shown that the rate of nitrogen application had a significant effect on concentrate feeding. Since the rate of nitrogen application is likely to be correlated with stocking rate and yield per cow, then this second relationship is liable to specification bias. Thirdly, the system is described as a causal chain, yet it is clearly not completely recursive but is simultaneous in parts. Fourthly, at least one of the variables—the rate of nitrogen application—introduces the problem of 'errors in variables' into the analysis, since it is derived from a previous regression and therefore contains a stochastic component. In addition, the regression it was derived from was subject to the same source of bias. The review has been purposefully hypercritical to date because the reviewers feel that the considerable effort and interesting intuitive ideas embodied in the report have not led to the type of analysis that could have been obtained. One reason for this could very well be that the data used in the report were not entirely suited to the objectives of the analysis. In other words, the author did not have to hand, all the variables that were needed for the purpose of the study.

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* Note that the classes have to be formulated so that we do not have a sparse number of observations within each class. This corresponds to amalgamation of classes in covariance analysis to avoid the problem of a very low number of degrees of freedom of a 'within class' regression.

Calf Supplies in the United Kingdom, Hill (18), is the final paper covered by this review. Within his paper, Hill attempts to explain variations in the annual percentage of calves slaughtered over the period 1955/56 to 1966/67. In particular, he regresses the percentage of calves slaughtered on the deflated price of rearing calves, the deflated level of calf subsidy and time. The deflator used is the retail price index. The calf price and time are found to be significant with the expected signs whereas the calf subsidy is found to be non-significant. Two points occur to the reviewers. Firstly, the level of subsidy may influence calf slaughterings through the calf price since the subsidy is often not paid to the farmer who makes the rearing decision; secondly, there may be some simultaneity between calf price and the percentage of calves slaughtered. These hypotheses would add a cautionary note to Hill's conclusions but clearly need testing first.

Appendix I

THE METHODOLOGY OF MARKOV CHAIN ANALYSIS

Suppose that r possible states are delineated and these are denoted by $s_i(i = 1, \ldots, r)$. For example, suppose r different herd size groups are distinguished and s_i therefore refers to the ith herd size group. The probability that state i occurs at trial t is denoted by:

$$P(s_{it}) = z_{it} \qquad (1)$$

In our example, z_{it} therefore refers to the probability that the average producer is in the ith herd size group at time t—that is, it represents the proportion of herds in the ith herd size group at time t. Various types of Markov processes may then be formulated. Thus a *zero-order* Markov process assumes that states occur independently on successive trials. Therefore, the probability of the sequence s_i on trial t and s_j on trial $t + 1$ is denoted by:

$$P(s_{it}, s_{jt+1}) = z_{it}\, z_{jt+1} \qquad (2)$$

On the other hand, in a *first-order* Markov chain, the probability of a state on one trial is conditional on which trial preceded it. Thus, if the probability of state j on trial t+1 conditional upon state i at trial t is denoted by p_{ij},

$$P(s_{jt+1}/s_{it}) = p_{ij} \qquad (3)$$

It is also assumed that the probability of a transition from i to j is the same for all trials. In our example, p_{ij} represents the probability of a producer with herd size in the ith group in one period moving into the jth herd size group in the following period. The probability of the sequence s_i on trial t and s_j on trial t+1 is given by:

$$P(s_{it}, s_{jt+1}) = z_{it}\, p_{ij} \qquad (4)$$

Therefore, in our example, equation (4) defines the proportion of herds transferring from the ith size group in period t to the jth size group in period $t + 1$.

Second or higher order Markov processes, which allow the transition probabilities to vary according to the outcome of two or more preceding trials, can also be defined but have so far not been used in empirical work. In fact, the first order Markov process, as defined above with stationary transition probabilities is the model commonly used. Such a process has two basic equations and one basic inequality:

$$z_{jt+1} = \sum_{i=1}^{r} z_{it} p_{ij} \tag{5}$$

and $$\sum_{j=1}^{r} p_{ij} = 1 \tag{6}$$

and $$p_{ij} \geq 0 \tag{7}$$

Equation (5) allows the calculations of the probability of s_j at trial $t + 1$, whilst equation (6) states that if the transition probabilities are arranged in an $r \times r$ matrix, P, then each row sum must equal unity. Finally, maximum likelihood estimates of the transition probabilities are given by:

$$\hat{P}_{ij} = \sum_{t=1}^{T} N_{ijt} \Big/ \sum_{j=1}^{n} \sum_{t=1}^{T} N_{ijt} \tag{8}$$

where N_{ijt} is the number of individuals in s_i in t who moved to s_j in $t + 1$, n is the total number of individuals and information on their movements is available for T time periods. The estimated transition probability matrix $\hat{P}$ is then used for predictive purposes. In particular, if we define the vector $Z_o = (z_{io})$ such that z_{io} represents the probability that state s_i occurs at time period $t = o$, then by equation (5):

$$\hat{Z}_k = Z_o\hat{P}^k \tag{9}$$

where $\hat{Z}_k$ is the vector of probabilities of the r states in time period k. Furthermore, if the total number of individuals (n) remains constant over all time periods of interest, then:

$$\hat{W}_k = W_o\hat{P}^k \tag{10}$$

where $W_o = (w_{oi})$ is a vector representing the distribution of individuals during time period $t = o$ (w_{oi} represents the number of individuals in state s_i in period o) and $\hat{W}_k$ is the predicted configuration vector during time period $t = k$.

Appendix II

GROUPING, HETEROSCEDASTICITY AND WEIGHTED REGRESSION

Suppose the relationship amongst the original units of observation is:

$$Y_i = \alpha + \beta X_i + u_i \qquad (1)$$

where $E(u_i) = O$ for all $i = 1, \ldots T$

$$\text{and } E(u_i\, u_j) = \begin{cases} O \text{ for } i \neq j \\ \sigma^2 \text{ for } i = j \end{cases}$$

Suppose these units of observation are grouped into n size groups with w_i observations within the i^{th} size group. Then, for group averages:

$$\overline{Y_i} = \alpha + \beta \overline{X_i} + \bar{u}_i \qquad i = 1, \ldots n \qquad (2)$$

where $E(\bar{u}_i) = O$

$$E(\bar{u}_i\, \bar{u}_j) = \begin{cases} O \text{ for } i \neq j \\ \sigma_u{}^2/w_i \text{ for } i = j \end{cases}$$

If the w_i are unequal, then the disturbances do not have a constant variance and the application of unweighted least squares is inefficient. However, following Johnston (36) pp. 207–208, homoscedasticity can easily be obtained by proper transformation of the variables

$$\text{Define the diagonal matrix } \sqrt{W} = \begin{bmatrix} \sqrt{w_1} & o & ..o \\ o & \sqrt{w_2} & ..o \\ . & .. & . \\ . & .. & . \\ o & o & .\sqrt{w_n} \end{bmatrix}$$

If equation (2) is written in matrix form as:

$$Y = X\beta + u \qquad (3)$$

Then, the correct transformation is obtained by multiplying (3) by $\sqrt{W}$.:

$$\sqrt{W}Y = \sqrt{W}X\beta + \sqrt{W}u \qquad (4)$$

The application of least squares to (4) gives the estimate:

$$\hat{\beta} = (X' \sqrt{W} \sqrt{W}X)^{-1} X'\sqrt{W}\sqrt{W}Y \qquad (5)$$

Computationally, the same result is derived more easily by minimizing a weighted sum of squares of the residuals from the untransformed equation (equation (3)). The weights are defined by the matrix:

$$W = \begin{bmatrix} w_1 & 0 & . & . & 0 \\ 0 & w_2 & . & . & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & . & & w_n \end{bmatrix}$$

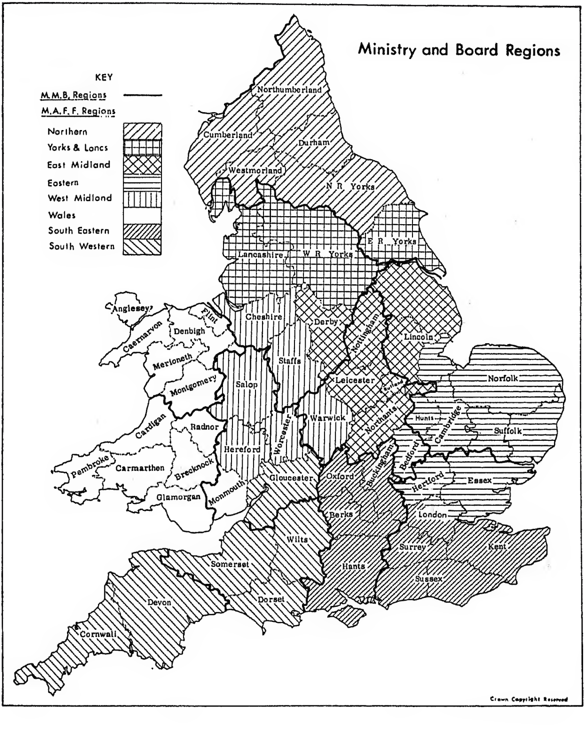
If e is the vector of residuals from $Y = X\hat{\beta} + e$, then we minimize $e'We$ to obtain the estimator:

$$\hat{\beta} = (X'WX)^{-1} X'WY \qquad (6)$$

and (6) is identical to (5).

Appendix III

DEFINITION OF MILK MARKETING BOARD AND MINISTRY OF AGRICULTURE, FISHERIES AND FOOD REGIONS



M.M.B. REGIONS

NORTHERN
- Cumberland
- Durham
- Northumberland
- Westmorland
- Yorks: E.R.
- Yorks: N.R.

NORTH WESTERN
- Cheshire
- Lancashire
- Yorks: W.R.
- Derby
- Stafford

EASTERN
- Lincs: Kesteven
- Cambridge and Ely
- Huntingdon
- Lincs: Holland
- Norfolk
- Lincs: Lindsey
- Peterborough
- East Suffolk
- West Suffolk

EAST MIDLAND
- Bedford
- Leicester
- Northampton
- Nottingham
- Warwick
- Rutland

WEST MIDLAND
- Gloucester
- Hereford
- Monmouth
- Worcester
- Shropshire

NORTH WALES
- Anglesey
- Caernarvon
- Denbigh
- Flint
- Merioneth
- Montgomery

SOUTH WALES
- Brecon
- Cardigan
- Carmarthen
- Glamorgan
- Pembroke
- Radnor

SOUTHERN
- Berkshire
- Buckingham
- Hampshire
- Oxford
- Isle of Wight

MID WESTERN
- Dorset
- Somerset
- Wiltshire

FAR WESTERN
- Devon
- Cornwall

SOUTH EASTERN
- Essex
- Hertford
- Kent
- Gt. London
- Surrey
- East Sussex
- West Sussex

M.A.F.F. REGIONS

NORTHERN

- Cumberland
- Durham
- Northumberland
- Westmorland
- Yorks: N.R.

YORK AND LANCS

- Lancashire
- Yorks: E.R.
- Yorks: W.R.

EAST MIDLAND

- Derby
- Leicester
- Lincs: Kesteven
- Lincs: Lindsey
- Northampton
- Nottingham
- Rutland

EASTERN

- Bedford
- Cambridge and Ely
- Essex
- Gt. London(Part)
- Hertford
- Hunts and Peterborough
- Lincs: Holland
- Norfolk
- Suffolk

WEST MIDLAND

- Cheshire
- Hereford
- Shropshire
- Stafford
- Warwick
- Worcester

WALES

- Anglesey
- Brecon
- Caernarvon
- Cardigan
- Carmarthen
- Denbigh
- Flint
- Glamorgan
- Merioneth
- Monmouth
- Montgomery
- Pembroke
- Radnor

SOUTH EASTERN

- Berkshire
- Buckingham
- Gt. London (Part)
- Hampshire
- Isle of Wight
- Kent
- Oxford
- Surrey
- East Sussex
- West Sussex

SOUTH WESTERN

- Cornwall
- Devon
- Dorset
- Gloucester
- Somerset
- Wiltshire

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MINISTRY OF
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Aspects of Dairy Economics

1966-1969

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Foreword

RESEARCH into the economics of milk production in England and Wales is undertaken by Departments of Agricultural Economics at certain universities. Many of the studies are sponsored and financed jointly by the Ministry of Agriculture, Fisheries and Food and the Milk Marketing Board, and the results are published from time to time in various journals and university reports. This publication reviews that research and presents information from other investigations and statistical analyses undertaken during the years 1966–69.

The text has been prepared by a group of agricultural economists under the Chairmanship of Mr. V. H. Beynon, B.Sc. (Agric. Econ.) of the University of Exeter. The other members of the Group were Mr. G. Allanson, B.A., M.Sc., of Wye College (University of London), Mr. J. A. Evans, B.Sc., of the Ministry of Agriculture, Fisheries and Food and Mr. R. E. Williams, M.Sc. (Econ.), of the Milk Marketing Board, who acted as joint editor with Mr. Beynon.

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Ministry of Agriculture, Fisheries and Food
August 1970